NUMERICAL PROBLEMS IN PHYSICS

For Class IX

WITH OBJECTIVE EVALUATION

Also useful for
- National Talent Search Examination
- National Defence Academy Examination
- Combined Defence Services Examination

S MALHOTRA

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For Class IX

WITH OBJECTIVE EVALUATION

S Malhotra

Delhi Public School
RK Puram
New Delhi

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In the everlasting memory of my father

Late Gurbax Lal Malhotra

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PREFACE

Physics is an extremely important branch of science, and has developed rapidly in the last few decades. The study of Physics calls for logical and analytical thinking. Solving numerical problems helps a student develop the mental faculties required for such study, and is also a satisfying experience. However, it has been the general experience of science teachers that students find it difficult to solve numerical problems. There has also been a dearth of good books on numerical physics. I have come across many students who have not solved a single numerical throughout their career. They were either scared of calculations or detested doing them. Some students simply read a few solved numericals and never attempt doing unsolved exercises. The situation can be rectified by giving the students regular practice in solving numericals. Care should be taken not to force it on them; instead they should be motivated.

It is generally felt that the traditional system of examinations overemphasizes "learning-by-rote" rather than acquiring an indepth understanding of the subject. But, of late, objective-type questions have been introduced to meet the situation. Such questions test the skills required to solve specific problems. As the time allotted for these tests is limited, students should have more practice before taking their final examination.

Apart from students of Class IX, this book will also meet the needs of those appearing for competitive examinations such as the NTSE and the entrance examinations for the IIT, NDA, MBBS, and so on.

The salient features of this book are as follows.

1. The solved numerical problems have been graded according to their degree of difficulty.
2. Difficult problems for more advanced students have been included in each chapter.
3. Numerical problems drawn from various competitive examinations are included.
4. Each chapter includes a large number of 'objective-type questions', 'matching the items' and 'true or false statements' along with their answers. They will help those appearing in the competitive examinations mentioned earlier.
5. SI units have been emphasized wherever necessary.

I express my gratitude to Mr R S Lugani, Principal, Delhi Public School, RK Puram, who has always been a source of inspiration for me as an author.

I express my special thanks to my wife Sukhvarsha, daughter Sherry and son Sunny. Without their help and sacrifice this book would not have been possible.

I dedicate this book to my late father who brought my academic career to a fruitful culmination.

All suggestions for further improvement of this book will be gratefully accepted.

S MALHOTRA

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UNIT ONE
DESCRIBING MOTION

REVIEW CONCEPTS

Origin is a fixed point with respect to which the position of any object changes.

Distance is the actual length of the path covered by a body during the whole journey, without taking into consideration its direction. It is a scalar quantity.

Displacement is the distance in a particular direction. It is a vector quantity.

Speed is the rate of change of distance.

Average speed is defined as the total distance travelled, divided by the total time taken.

Initial speed is that speed with which a body starts its motion in the beginning. It is denoted by u.

It is zero whenever a body starts from rest.

Final speed is that speed which is acquired by the body after its start. It is denoted by v. When a body finally comes to rest its final speed is zero.

Scalar quantities are those which have *magnitude* only, but, *vector quantities* have both *magnitude* and *direction*. For example, the amount of time and speed are scalar quantities because they have only magnitude, but acceleration and force are vector quantities because they have magnitude and direction. The magnitude of a vector is called modulus of the vector.

When a body covers unequal distances in equal intervals of time, or its direction changes or both change, its velocity is said to be *variable*.

When a body travels equal distances in equal intervals of time, however small the interval of time may be, its velocity is said to be *uniform*.

The rate of change of *angular displacement* is called *angular velocity*.

Acceleration of a body is defined as the rate of change of velocity. Acceleration has both magnitude and direction, hence it is a vector quantity.

The rate of change of angular velocity is called ***angular acceleration***.

Centripetal acceleration If a body is moving along the circumference of a circle, then the acceleration produced is directed towards the centre of the circle. This acceleration is called *centripetal acceleration*. Force due to centripetal acceleration, acting towards the centre, is called the *centripetal force*.

Retardation When the final speed of a body is less than its initial speed, the body is said to be retarding.

Retardation can also be expressed as acceleration with a minus sign.

Uniform speed Whenever a body covers equal distances in equal intervals of time, speed is said to be uniform.

Uniform acceleration If velocity increases by equal amounts in equal intervals of time in a straight line however small the intervals of time may be.

Graphs and their uses Graphs provide much more information than observations recorded in tabular form. From the graphs one can find out even those values which are not given in the data. The position of the moving body can be easily located at any instant of time. One can also come to know whether the body is moving with uniform speed or not. To plot a graph always take the independent quantity on the x-axis and the dependent on the y-axis.

Slope of the graphs

(i) The slope of the distance-time graph gives the speed of the moving body.

(ii) The distance travelled by a body can be obtained by determining the area under the speed-time graph.

(iii) The slope of the velocity-time graph gives the acceleration of the moving body.

(iv) By plotting the distance-time graph of two bodies, one can find out when and where the two bodi oss each other.

Formulae

$$\text{Speed or velocity} = \frac{\text{distance}}{\text{time}} = \frac{s}{t}$$

where s—distance and t—time

$$\text{Average speed } v_{av} = \frac{\text{Total distance}}{\text{Total time}}$$

Equations of motion

(i) $v = u + at$ or $v - u = at$

or $a = \dfrac{v - u}{t}$ or $t = \dfrac{v - u}{a}$

where v = final speed
u = initial speed
a = acceleration and
t = time

(ii) $v^2 - u^2 = 2as$ or $v^2 = u^2 + 2as$

(iii) $s = ut + ½\,at^2$

Angular speed

$$\omega = \frac{\theta}{t}, \quad \text{also} \quad \omega = \frac{v}{r}$$

Distance covered as area under speed-time graph.

(a) For uniform speed:
Distance covered = speed × time interval
Distance covered = Area of the rectangle

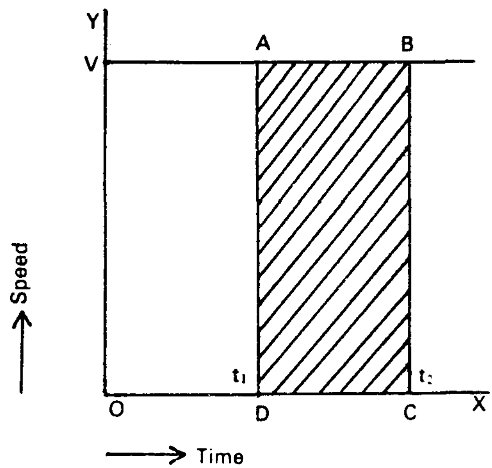


Fig. 1.1 Graph between uniform speed and time

(b) For non-uniform speed:
Distance covered = speed × time
Distance covered = Area under the staircase graph

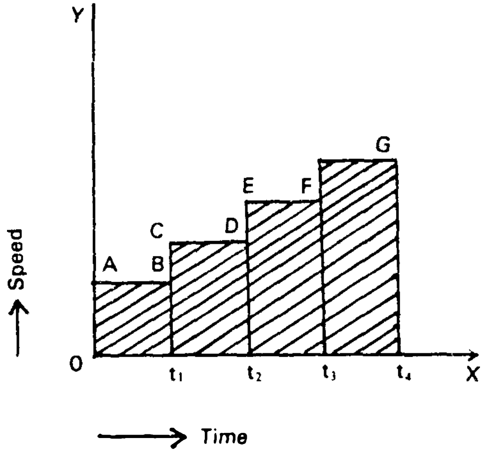


Fig. 1.2 Graph between non-uniform speed and time

NUMERICAL PROBLEMS (SOLVED)

EXAMPLE 1 A car travels 30 km at a uniform speed of 40 km/h and the next 30 km at a uniform speed of 20 km/h. Find its average speed.

Solution: Given,

Total distance(d) = 30 + 30 = 60 km

Speed for the first 30 km (v_1) = 40 km/h

Speed for next 30 km (v_2) = 20 km/h

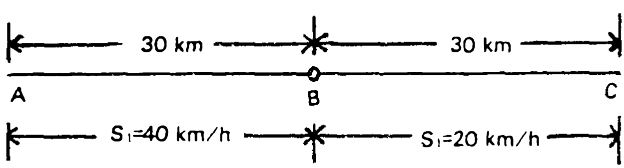


Fig. 1.3

To calculate: Average speed (v_{av}) = ?

Formula to be used : $\frac{\text{Total distance } (d)}{\text{Total time } (t)}$

Now in this problem we are not given the total time. So our first problem is to find out the total time from the two speeds given to us by using the formula

$$\text{Time } (t) = \frac{\text{distance}}{\text{speed}}$$

(i) time (t_1) in going from A to B (Fig. 1.3)

$$= \frac{30}{40} = \frac{3\text{h}}{4} = 45 \text{ min}$$

(ii) time (t_2) in going from B to C

$$= \frac{30}{20} = 1 \text{ hr } 30 \text{ min} = 90 \text{ min}$$

$$\text{Total time} \quad (t) = t_1 + t_2$$

$$= 45 + 90 = 135 \text{ min}$$

=> $$t = \frac{135}{60} \text{ h}$$

Hence, $$v_{av} = \frac{60 \times 60}{135} = \frac{80}{3} \text{ km/h}$$

EXAMPLE 2 On a 60 km track a train travels the first 30 km at a uniform speed of 30 km/h. How fast must the train travel the next 30 km so as to average 40 km/h for the entire trip?

Solution: Given,

Total distance (d) = 60 km

Speed (S) during the first half journey = 30 km/h

Average speed (v_{av}) = 40 km/h

To calculate : Speed (v_2) for the 2nd half = ?

Formula to be used : $$v_{av} = \frac{\text{Total distance}}{\text{Total time}}$$

or $$v_{av} = \frac{\text{Total distance}}{t_1 + t_2}$$

or $$40 = \frac{60}{1 + \dfrac{30}{v_2}} = 40 (v_2 + 30) = 60$$

=> $$v_2 = 60 \text{ km/h}$$

EXAMPLE 3 Figure 1.4 shows the distance-time graph of three people A, B and C. On the basis of this graph answer the following questions:

(a) Which of the three is travelling the fastest?

(b) Are all three ever at the same point on the road?

(c) When B passes A where is C?

(d) How far did B travel between the time he passed C and A?

(e) How far did C travel between the time he passed B and A?

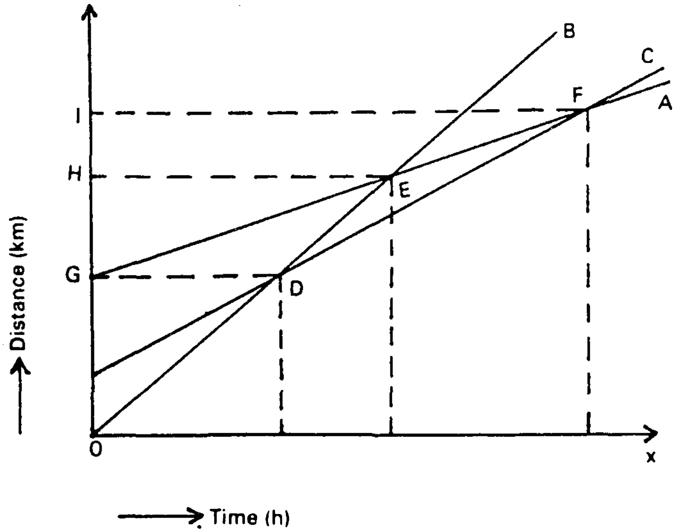


Fig. 1.4

Solution:

(a) B is travelling fastest since slope of distance-time graph determines the speed of a person. Since the slope of the graph for B is the maximum (from Fig. 1.4).

(b) No, because the three lines A, B and C do not meet at one point.

(c) When B and A meets, C is at the position E, i.e. C is lagging behind A and B.

(d) B meets C and D which corresponds to G on the y-axis and B meet's A at E which corresponds to H on the y-axis. Hence the distance travelled by B between the time he passed C and A is equal to GH.

(e) C meets B at D, which corresponds to G on the y-axis and C meets A at F, which corresponds to I on the y-axis. Hence the distance travelled by C between the time he passed B and A is equal to GI.

EXAMPLE 4 The following is the distance-time table of a moving car.

Time	Distance
10.05 am	0 km

10.25 am	5 km
10.40 am	12 km
10.50 am	22 km
11.00 am	26 km
11.10 am	28 km
11.25 am	38 km
11.40 am	42 km

(a) Use a graph paper to plot the distance travelled by the car versus time.

(b) When was the car travelling with the greatest speed?

(c) What is the average speed of the car?

(d) What is the speed between 11.25 am to 11.40 am?

(e) During a part of the journey, the car was forced to slow down to 12 km/h. At what distance did this happen.

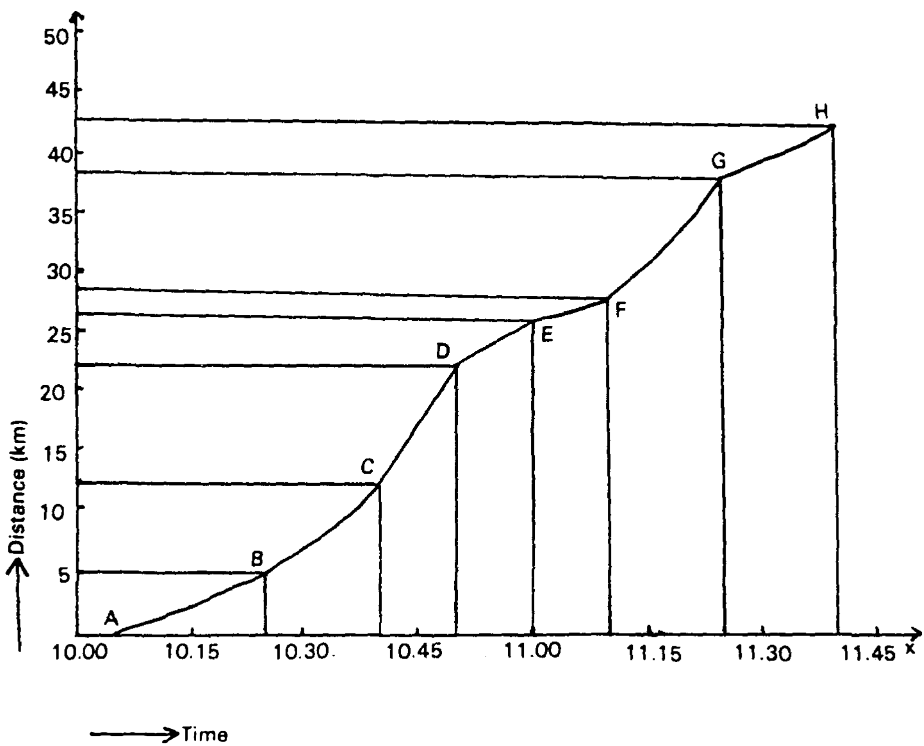


Fig. 1.5

Solution:

(a) A plot of distance versus time is as shown in Fig. 1.5

(b) The slope of the graph between C and D is maximum. Hence the car has the greatest speed between 10.40 am to 10.50 am.

(c) Average speed of the car $= \dfrac{\text{Total distance}}{\text{Total time taken}}$

$$= \frac{42 \text{ km}}{(11.40 - 10.05) \text{ h}}$$

$$= \frac{42 \text{ km}}{1\text{h } 35 \text{ min}} = \frac{42 \times 60}{95} = 26.53 \text{ km/h}$$

(d) From the graph the speed between 11.25 am and 11.40 am

$$= \frac{\text{Distance covered}}{\text{Time taken}} = \frac{42 - 38}{(11.40 - 11.25)} = \frac{4 \text{ km}}{15 \text{ min}}$$

$$= \frac{4 \times 60}{15} = 16 \text{ km/h}$$

(e) The car is moving at 12 km/h between 11.00 am and 11.10 am (from the graph as done in part (d)) or between 26 km to 28 km.

EXAMPLE 5 A train travels at 60 km/h for 0.52 hour, 30 km/h for the next 0.24 hour and then 70 km/h for the next 0.71 hour. What is the average speed of the trip?

Solution: Given,

First speed (v_1)	= 60 km/h
Time for this part of the trip (t_1)	= 0.52 h
Second speed (v_2)	= 30 km/h
Time for second part (t_2)	= 0.24 h
Third speed (v_3)	= 70 km/h
Time for third part (t_3)	= 0.71 h

To calculate : Average speed (v_{av}) = ?

Formula to be used: $\dfrac{\text{Total distance } (d)}{\text{Total time taken } (t)}$

Now in this case we are not given the total distance travelled, so first of all we will find out the distance covered during the three given intervals by using the formula.

$$\text{distance} = \text{speed} \times \text{time}$$

(i) First part $(d_1) = v_1 \times t_1 = 60 \times 0.52 = \frac{156}{5}$ km

(ii) Second part $(d_2) = v_2 \times t_2 = 30 \times 0.24 = \frac{36}{5}$ km

(iii) Third part $(d_3) = v_3 \times t_3 = 70 \times 0.71 = \frac{497}{10}$ km

Total distance $(d) = d_1 + d_2 + d_3$

$$= \frac{156}{5} + \frac{36}{5} + \frac{497}{10} = \frac{881}{10} \text{ km} = 88.1 \text{ km}$$

Total time taken $(t) = t_1 + t_2 + t_3$

$$= 0.52 + 0.24 + 0.71 = 1.47 \text{ h}$$

$$\therefore \qquad v_{av} = \frac{88.1}{1.47} = 59.93 \text{ km/h}$$

EXAMPLE 6 A ship is moving at a speed of 56 km/h. One second later it is moving at 58 km/h. What is its acceleration?

Solution: Given,

Initial speed (u) = 56 km/h

Final speed (v) = 58 km/h

Time taken (t) = 1 s = $\frac{1}{60 \times 60}$ h

To calculate: Acceleration (a) = ?

Formula to be used : $a = \frac{v - u}{t}$

$$a = \frac{58 - 56}{\frac{1}{60 \times 60}} = 7200 \text{ km/h}^2$$

EXAMPLE 7 The driver of a car travelling at 52 km/h applies the brakes and accelerates uniformly. The car stops in 5 s. Another driver going at 34 km/h applies his brakes slower and stops after 10 s. On the same graph, plot the speed versus time graph for the two cars. Which of the two cars travelled farthest after the brakes were applied?

Solution: Given,

Speed of first car (v_1) = 52 km/h = $\frac{52 \times 1000}{3600}$ m/s

Speed of second car (v_2) = 34 km/h = $\frac{34 \times 1000}{3600}$ m/s

Time for first car (t_1) = 5

Time for second car (t_2) = 10

To calculate : Distance travelled (d) = ?

Formula to be used : Distance = Area under the speed-time graph

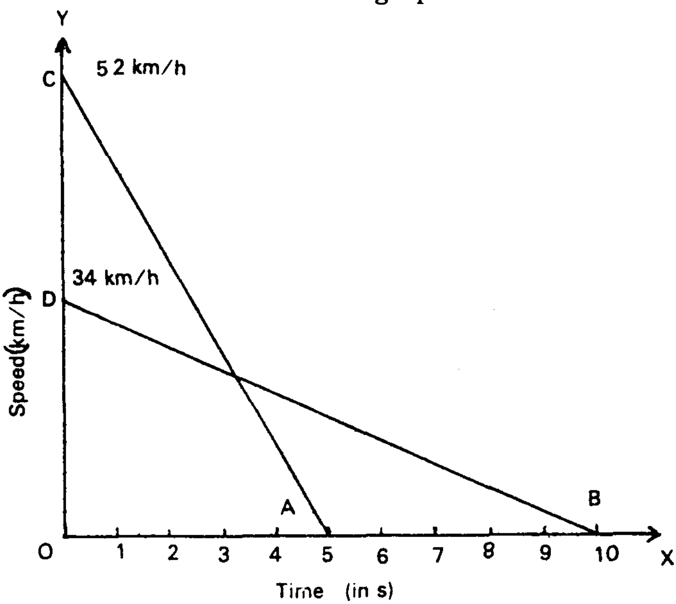


Fig. 1.6

Case I

From Fig. 1.6,

$$d_1 = \frac{1}{2} \times OA \times OC = \frac{1}{2} \times 5 \times \frac{52 \times 1000}{3600} = 41.66 \text{ m}$$

Case II

From Fig. 1.6,

$$d_2 = \frac{1}{2} \times OB \times OD = \frac{1}{2} \times 10 \times \frac{34 \times 1000}{3600} = 47.22 \text{ m}$$

$\therefore$ The second car will go farther after applying the brake.

EXAMPLE 8 The speed-time graph of a body is shown in Fig. 1.7. Find the distance travelled from 10.20 am to 10.40 am.

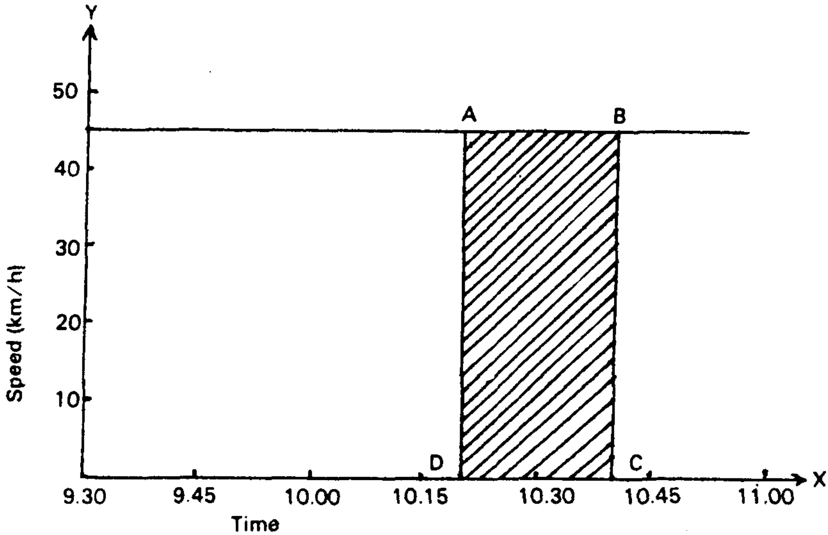


Fig. 1.7

Solution: Given,

Time interval $(t_2 - t_1) = 10.40 - 10.20$

$$= 20 \text{ min} = \frac{20}{60} \text{ h}$$

Speed (s_1) = 45 km/h (from graph)

To calculate : Distance travelled (d) = ?

Formula to be used : Distance travelled = Area under the curve ABCD

$$\therefore \text{Distance } (d) = AB \times CD = \frac{20}{60} \times 45 = \frac{1}{3} \times 45 = 15 \text{ km}$$

EXAMPLE 9 The speed of an object can change in several ways. A few speed-time graphs for non-uniform motion of objects moving along a straight line are shown in Figs. 1.8 (a), (b), (c) and (d).

Which of the graphs represent the motion of a body whose speed is

(a) Oscillating
(b) Uniform
(c) Increasing with time
(d) Decreasing with time

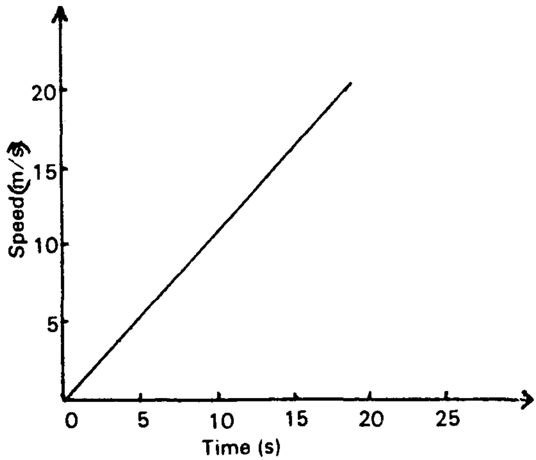


Fig. 1.8 (a) Graph depicting the motion of a body with increasing speed

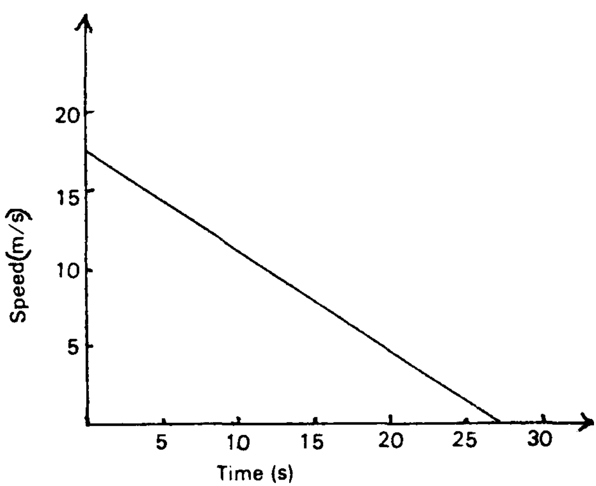


Fig. 1.8 (b) Graph depicting the motion of a body with decreasing speed

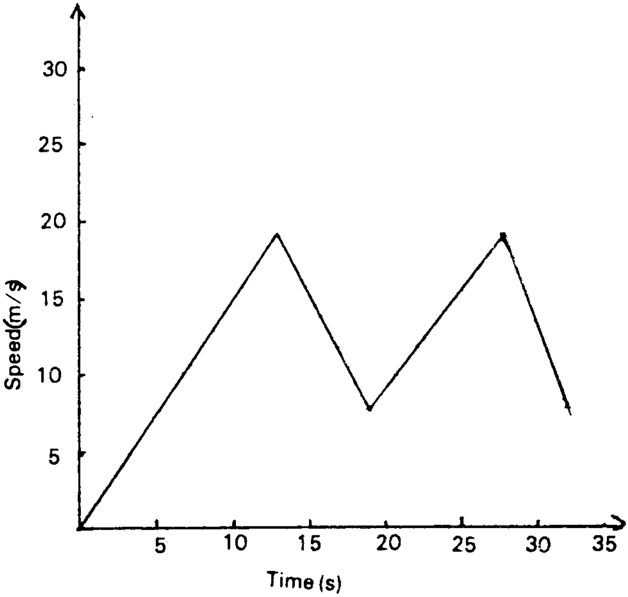


Fig. 1.8 (c) Graph depicting the motion of a body with oscillating (variable) speed

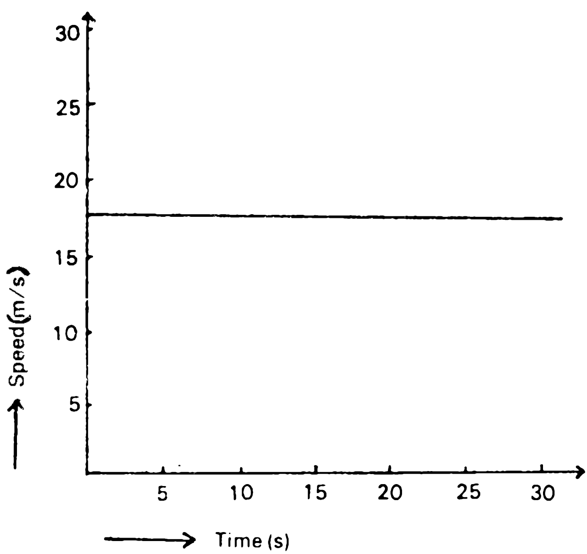


Fig. 1.8 (d) Graph depicting the motion of a body with uniform speed

Solution:

(a) Figure 1.8 (c). In this case the speed is oscillating with time or is alternately increasing and decreasing.

(b) Figure 1.8 (d) shows uniform speed as it is a straight line parallel to the x-axis.

(c) Figure 1.8 (a) shows increasing speed with respect to time.

(d) Figure 1.8 (b) shows decreasing speed with respect to time.

EXAMPLE 10 Figures 1.9 (a) and (b) show the speed-time graph of two cars. Using the graph answer the following questions.

(a) What is the acceleration of the car A and car B in the first two hours, in the next two hours and in the last two hours?

(b) What is the total distance travelled by the two cars?

(c) What is the average speed of the two cars?

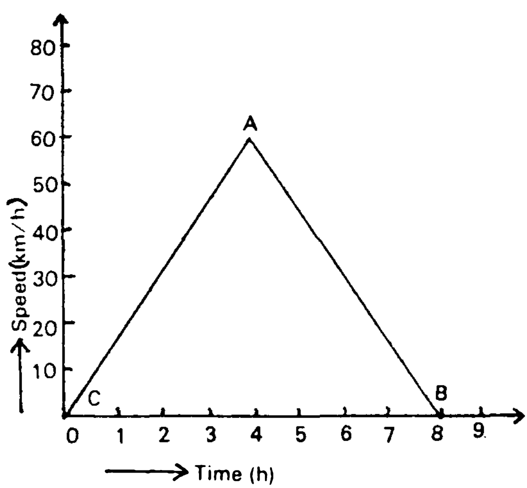
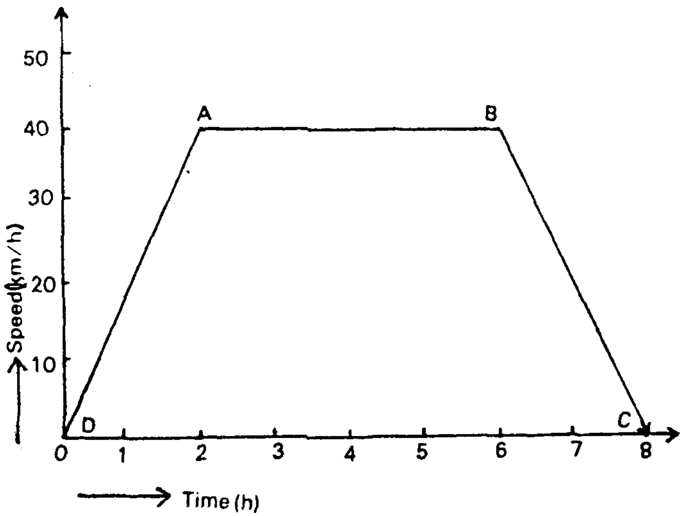
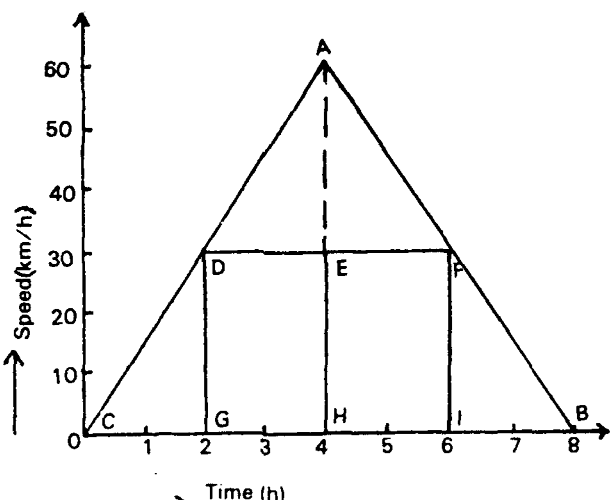


Fig. 1.9 (a)



Car (B)

Fig. 1.9 (b)



Car (A)

Fig 1.10 (a)

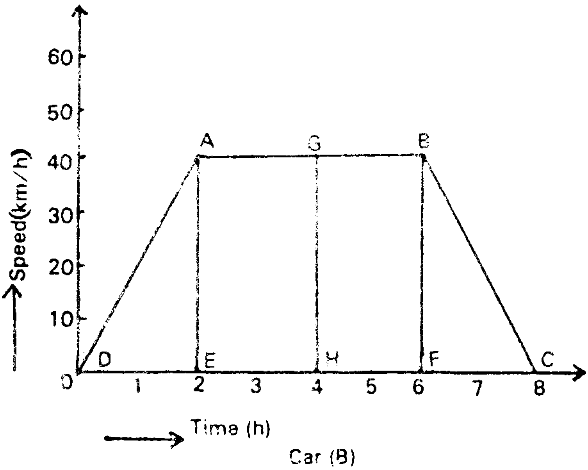


Fig 1.10 (b)

Solution:

(i) Acceleration of car A for the first two hours (from Fig. 1.10 (a))

$$= \frac{DG}{CG} = \frac{30}{2} = 15 \text{ km/h}^2$$

Similarly, acceleration of car B for the first two hours (from Fig. 1.10 (b))

$$= \frac{AE}{DE} = \frac{40}{2} = 20 \text{ km/h}^2$$

Acceleration of car A for the next two hours (from Fig. 1.10(a))

$$= \frac{AE}{GH} = \frac{30}{2} = 15 \text{ km/h}^2$$

Acceleration of car B for the next two hours (from Fig. 1.10(b))

$$= \frac{AG}{EH} = 0 \text{ km/h}^2$$

Acceleration of the car A for the last two hours,

$$= \frac{FI}{IB} = \frac{-30}{2} = -15 \text{ km/h}^2$$

Negative sign shows that it is retardation, i.e., the car is decelerating.

Similarly, acceleration of the car B for the last two hours,

$$= \frac{BF}{FC} = \frac{-40}{2} = -20 \text{ km/h}^2$$

Again the negative sign shows that the car is decelerating.

(ii) Total distance travelled = Area under the speed-time graph

For car A

$$\text{distance } (d) = \frac{1}{2} \times BC \times AH = \frac{1}{2} \times 8 \times 60 = 240 \text{ km}$$

Similarly for car B

Total distance = Area of the Δ ADE + Area of the rectangle ABFE + Area of the Δ BCF

$$= \left(\frac{1}{2} \times AE \times DE\right) + (AB \times BF) + \left(\frac{1}{2} \times 40 \times 2\right)$$

$$= 40 + 160 + 40 = 240 \text{ km}$$

$$\text{Average speed } (v_{av}) = \frac{\text{Total distance}}{\text{Total time taken}} = \frac{240}{8} = 30 \text{ km/h}$$

EXAMPLE 11 A car travels a certain distance with a speed of 50 km/h and returns with a speed of 40 km/h. Calculate the average speed after the whole journey.

Solution: Given,

Speed in the forward direction (v_1) = 50 km/h

Speed during the return journey (v_2) = 40 km/h

To calculate : Average speed (v_{av}) = ?

Formula to be used : $\frac{\text{Total distance}}{\text{Total time taken}} = \frac{d}{t}$

Now, in this case we are neither given the total distance nor the total time taken.

Let us say the distance travelled in the forward direction = x

Distance travelled during the return journey = x

Hence, Total distance (d) = $x + x = 2x$

∴ Time (t_1) during forward journey = $\frac{x}{50}$ h

and Time (t_2) during the return journey = $\frac{x}{40}$ h

$$\text{Total time taken } (t) = \frac{x}{50} + \frac{x}{40} = \frac{9x}{200} \text{ h}$$

$$\therefore \quad v_{av} = \frac{2x}{9x/200} = \frac{2x \times 200}{9x} = \frac{400}{9} = 44.44 \text{ km/h}$$

EXAMPLE 12 The velocity-time graph of an ascending passenger lift is given below. What is the acceleration of the lift?
(a) acting between O and A ?
(b) acting between A and B ?
(c) acting between B and C ?

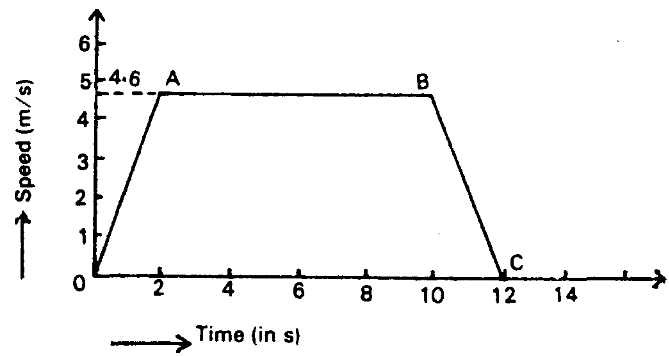


Fig. 1.11

Solution:

(a) Between O and A

From the graph,

Change in speed = 4.6 – 0 = 4.6 m/s

Change in time = 2 – 0 = 2 s

$$\text{Acceleration } (a) = \frac{\text{Change in speed}}{\text{Time taken}} = \frac{4.6}{2} = 2.3 \text{ m/s}^2$$

(b) Between A and B

From the graph, Change in speed = 0

Since, A to B, the graph is parallel to x-axis showing no change in speed

$\therefore$ Acceleration is zero.

(c) From B to C

From the graph,

Change in speed = 0 – 4.6 = – 4.6 m/s

Time taken = 12 – 10 = 2 s

$\therefore$ Acceleration (a) $= \dfrac{-4.6}{2} = -2.3$ m/s^2

Negative sign shows that the body is retarding.

EXAMPLE 13 Calculate the value of acceleration for the position OP from the following displacement-time graph. What type of motion is represented by the position OP, PQ and QR of the graph ?

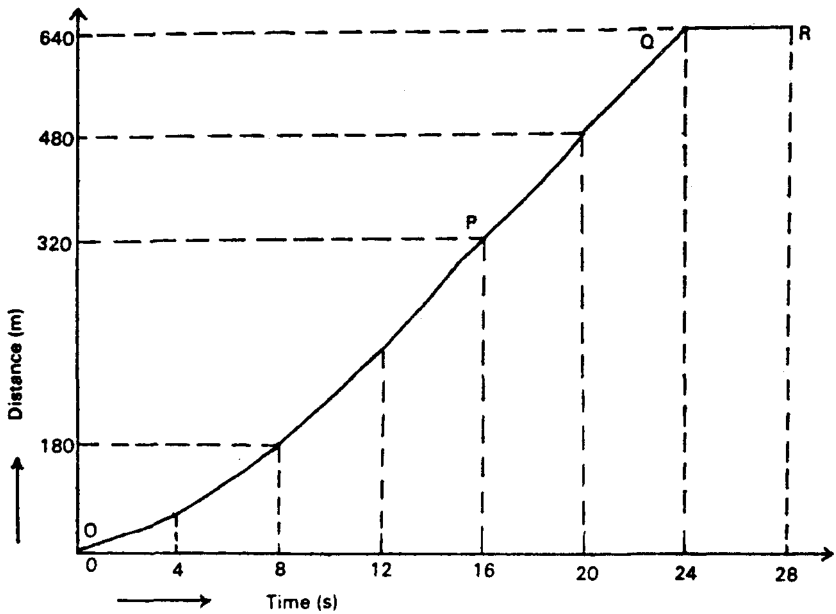


Fig. 1.12

Solution:

(i) Velocity at O = 0 m/s

$$\text{Velocity at P} = \frac{\text{Distance}}{\text{Time}} = \frac{320}{16} = 20 \text{ m/s}$$

Acceleration for region OP = Rate of change of velocity

$$= \frac{20 - 0}{16} = \frac{5}{4} \text{ m/s}$$

(ii) OP shows non-uniform motion. PQ represents uniform motion.

QR represents that the body is at rest because distance covered in this duration is zero.

EXAMPLE 14 The distance between the house and the school of a boy is 3.6 km. If he takes 6 minutes to reach his school by car, calculate his speed in m/s. Also express his speed in km/h.

Solution: Given,

Distance (d) = 3.6 km = 3.6 × 10 m

Time (t) = 6 min = 6 × 60 = 360 s = $\frac{6}{60}$ h

To calculate : Speed (u) = ?
in m/s and km/h

Formula to be used: $v = \frac{d}{t} = \frac{3.6}{6/60} = \frac{3.6 \times 60}{6} = 36$ km/h

Also $v = \frac{3.6 \times 10}{360} = 10$ m/s

EXAMPLE 15 A railway train 200 m long, passes over a bridge 800 m long. Find the time it takes to cross the bridge when it is moving with a uniform velocity of 36 km/h.

Solution: Given,

Distance travelled = length of the train + length of the bridge = 200 + 800

d = 1000 m

Velocity (v) = 36 km/h = $\frac{3600}{360}$ = 10 m/s

To calculate : Time taken (t) = ?

Formula to be used : $t = \frac{d}{v}$

$\therefore$ $t = \frac{1000}{10} = 100$ s

EXAMPLE 16 A body has an average speed of 30 m/s. If its final speed is 40 m/s, did the body starts from rest or motion? If it started from motion what was its initial speed?

Solution: Given,

Average speed (v_{av}) = 30 m/s

Final speed (v) = 40 m/s

To calculate : Initial speed (u) = ?

Formula to be used : $v_{av} = \dfrac{v + u}{2}$

or $u = (2 \times v_{av}) - v$

Substituting the given values,

$$u = (2 \times 30) - 40 = 60 - 40 = 20 \text{ m/s}$$

Since, u = 20 m/s which is not zero. Therefore the body was initially not at rest.

EXAMPLE 17 A trolley while going down an inclined plane has an acceleration of 2 m/s. What will be its velocity 3 s after the start?

Solution: Given,

Acceleration (a) = 2m/s^2

Time (t) = 3 s

Initial speed (u) = 0

To calculate : Final velocity (v) = ?

Formula to be used : $v = u + at$

On substituting the given values,

$$v = 0 + (2 \times 3) = 6 \text{ m/s}$$

EXAMPLE 18 Figure 1.13 shows the displacement of a body moving along a straight line at different times. Calculate the velocity of the body as it moves from A to B, B to C and to D. Also calculate the displacement during the sixth second.

Solution: Given,

Graph as shown in Fig. 1.13

To Calculate : (i) Velocity (v) = ?

(ii) Displacement (d) = ?

Formula to be used :

(i) Velocity (v) $= \dfrac{d}{t}$ = Slope of the graph

(a) Velocity from A to B $= \dfrac{4 - 0}{5 - 0} = \dfrac{4}{5} = 0.8$ m/s

(b) Velocity from B to C $= \dfrac{4 - 4}{8 - 5} = \dfrac{0}{3} = 0$ m/s

(c) Velocity from C to D $= \dfrac{8 - 4}{10 - 8} = \dfrac{4}{2} = 2$ m/s

(ii) The displacement during the sixth second = 4 m (from the graph)

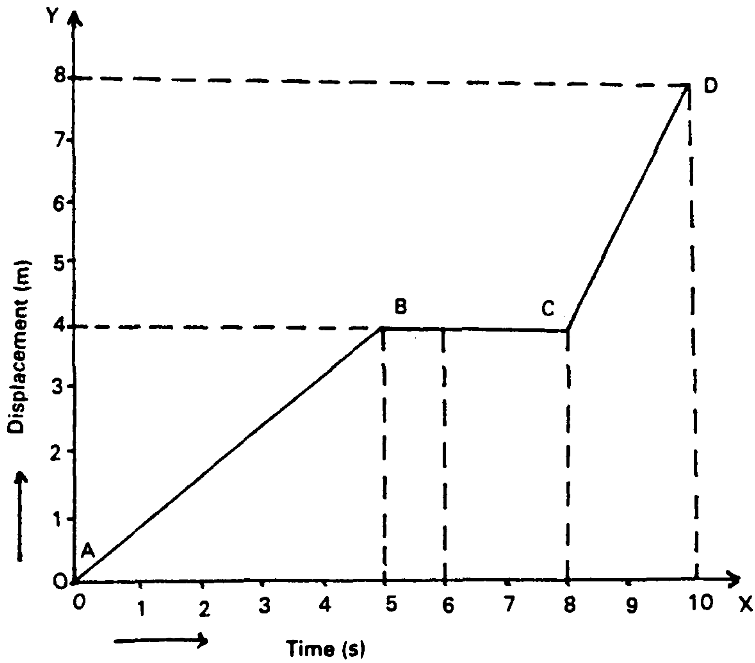


Fig. 1.13

EXAMPLE 19 Figure 1.14 represents a velocity-time graph of an object moving along a straight line.

(a) Describe the motion of the body during the 20 s.

(b) How far did the object travel in the first 2 s?

(c) What was the velocity of the object during the first 2 s?

(d) What was the velocity during the next 4 s?

(e) What was it during the last 4 s?

Solution:

(a) For part AB, the object moved with a unifom velocity, for part BC, it was at rest and for part CD, it again moved with some other uniform velocity.

(b) In the first 2 s, it covered 20 m.

(c) Since velocity is given by the slope of the displacement-time graph, i.e.

$$\text{Velocity} = \frac{\text{Displacement}}{\text{Time}}$$

Velocity during the first 2 s (along AB)

$$= \frac{(10 - 0)}{(2 - 0)} = 5 \text{ m/s}$$

(d) Velocity during the next 4 s (along BC)

$$= \frac{(10 - 10)}{(6 - 2)} = 0 \text{ m/s}$$

(e) Velocity during the last 4 s (along CD)

$$= \frac{(20 - 10)}{(10 - 6)} = 2.5 \text{ m/s}$$

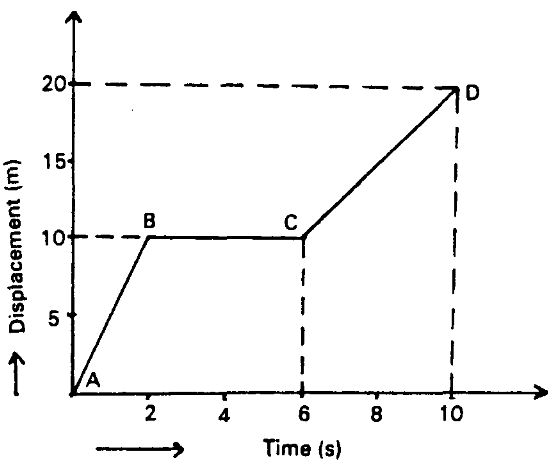


Fig. 1.14

EXAMPLE 20 Figure 1.15 shows the velocity-time graph of an object.

(a) Describe the motion of the object during 45 s.

(b) What is the total distance covered by the object ?

(c) What is its acceleration during the first 10 s ?

(d) What is the acceleration during the last 15 s ?

Solution:

(a) During the first 10 s, the object moved with uniform acceleration. During the next 20 s, it moved with uniform velocity, whereas during the last 15 s, it moved with uniform retardation.

(b) Total distance covered is given by the area of the velocity-time graph ABCD.

Distance covered during the first 10 s = area of Δ ABN

$$= \frac{1}{2} AN \times BN = \frac{1}{2}(10)(30) = 150 \text{ m}$$

Distance covered during the last 15 s = area of Δ CMD

$$= \frac{1}{2} MD \times CM = \frac{1}{2}(15)(30) = 225 \text{ m}$$

Distance covered during the next 20 s = area of rectangle BNMC

$$= NM \times BN = 20 \times 30 = 600 \text{ m}$$

Total distance covered = (150 + 600 + 225) m = 975 m

(c) Acceleration is given by the slope of the velocity-time graph.

Acceleration during the first 10 s

$$= \frac{BN}{AN} = \frac{-30 \text{ m/s}}{10 \text{ s}} = -3 \text{ m/s}^2$$

(d) During the last 15 s, the velocity has decreased from 30 m/s. Therefore, retardation during the last 15 s is given by

$$\frac{CM}{MD} = \frac{-30 \text{ m/s}}{5 \text{ s}} = -2 \text{ m/s}^2$$

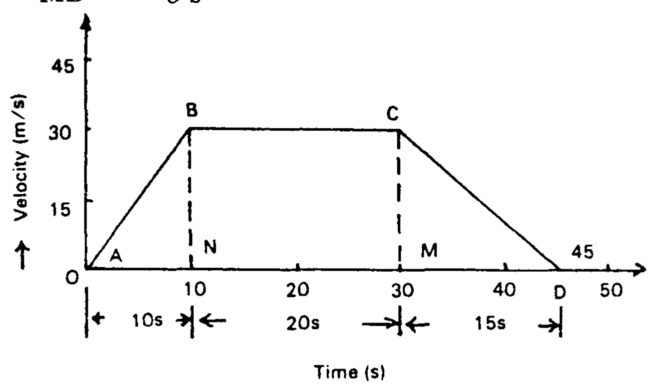


Fig. 1.15

EXAMPLE 21 A body covers half of its journey with a speed a m/s and the other half with a speed b m/s. Calculate the average speed of the body during the whole journey.

Solution: Given,

Speed (u_1) = a m/s

Speed (u_2) = b m/s

To calculate : Average speed (v_{av}) = ?

Formula to be used : $v_{av} = \dfrac{\text{Total distance}}{\text{Total time taken}}$

Suppose the total distance covered by the body is $2d$, out of which (d) is covered with a speed (a) and the other half (i.e., d) is covered with a speed (b). Let us suppose (t_1) and (t_2) be the time taken for the first and the second half respectively

$$t = \frac{d}{a} \text{ and } t = \frac{d}{b}$$

$$\text{Total time taken } (t) = t_1 + t_2$$

$$= \frac{d}{a} + \frac{d}{b}$$

$$= d\left(\frac{1}{a} + \frac{1}{b}\right)$$

Also, $$t_1 + t_2 = \frac{2d}{v_{av}}$$

$\therefore$ $$\frac{2d}{v_{av}} = d\left(\frac{1}{a} + \frac{1}{b}\right)$$

$$\frac{2}{v_{av}} = \left(\frac{a+b}{ab}\right)$$

$$v_{av} = \frac{2\,ab}{a+b} \text{ m/s}$$

EXAMPLE 22 Two stones are projected from the top of a tower 100 m high, each with a velocity of 20 m/s. One is projected vertically upward and the other vertically downwards. Calculate the time each stone takes to reach the ground and the velocity with which it strikes the ground?

Solution: Given (for the first stone)

Initial speed (u) = 20 m/s

Distance or height (h) = 100 m

Acceleration due to gravity (g) = – 9.8 m/s

(for the second stone)

Initial speed (u) = 20 m/s

Distance or height (h) = 100 m

Acceleration due to gravity (g) = 9.8 m/s

To calculate: (i) Time (t) = ?

(ii) Velocity (v) = ?

Formula to be used : (i) $v^2 - u^2 = 2gh$

(ii) $v = u + gt \Rightarrow t = \dfrac{v - u}{g}$

For first stone

$$v^2 - u^2 = 2gh$$

$$v^2 - (20)^2 = 2(-9.8)(100)$$

$$v^2 = -2360$$

$$v = -48.59 \text{ m/s}$$

$$t = \frac{v - u}{g} = \frac{-48.59 - 20}{-9.8} = 7 \text{ s}$$

For second stone

$$v^2 - u^2 = 2gh$$

$$v^2 - (20)^2 = 2(9.8)(100)$$

$$v^2 = (20)^2 + (2 \times 9.8 \times 100)$$

$$v = 48.59 \text{ m/s}$$

$$t = \frac{v - u}{g} = \frac{48.59 - 20}{9.8} = 2.92 \text{ s}$$

EXAMPLE 23 An artificial satellite takes 90 minutes to complete its revolution around the earth. Calculate the angular speed of the satellite.

Solution: Given,

Time (t) = 90 min = 90 × 60 = 5400 s

Angle (θ) = 2 π radians

To calculate : Angular speed (ω) = ?

Formula to be used : $\omega = \dfrac{\theta}{t}$

$$\omega = \frac{2\pi}{5400} = \frac{\pi}{2700} \text{ radians/s}$$

EXAMPLE 24 A merry-go-round of 10 m radius, with children sitting on it, is revolving at the rate of 1 revolution per minute. Calculate the speed of the children sitting on it and their angular velocity.

Solution: Given,

Angle (θ) = 2π radius
(in 1 min)

Radius (r) = 10 m

Time (t) = 1 min = 60 s

To calculate : v = ?

Formula to be used : $v = r\omega$

But we do not know the value of ω. Therefore first of all we will find out the value of ω by using the formula,

$$\omega = \frac{\theta}{t}$$

$$\omega = \frac{2\pi}{60} = \frac{\pi}{30} \text{ radius/sec}$$

$$v = r\omega$$

$$v = 10 \times \frac{\pi}{30} = \frac{\pi}{3}$$

$$v = 1.04 \text{ m/s}$$

EXAMPLE 25 Calculate the angular speed of the seconds hand of a clock, assuming that it moves with a uniform angular speed. If the length of the seconds hand is 2 cm, calculate the speed of the tip of the seconds hand?

Solution: Given,

Angle (θ) in one rotation = 2π rad.

Time (t) = 60 s

($\because$ seconds hand complete one rotation in 60 s and subtends an angle of 2π radius at the centre)

Radius (r) = 2 cm

To calculate : Speed (v) = ?

Formula to be used : $v = r\omega$

But here we do not know the value of ω. So first of all by using the formula $\omega = \theta/t$, we will find the value of ω

$$\therefore \quad \omega = \frac{2\pi}{60} = \frac{\pi}{30} \text{ rad/s}$$

$$\therefore \quad v = r \times \omega$$

$$= 2 \times \frac{\pi}{30} = \frac{\pi}{15} \text{ cm/s}$$

$$v = \frac{\pi}{15} \text{ cm/s}$$

NUMERICAL PROBLEMS (UNSOLVED)

1. A body moving with a speed of 36 km/h is brought to rest in 10 s. What is the negative acceleration and the distance travelled by the body before coming to rest? (Ans. 1 m/s^2, 50 m)

2. A train starts its journey from station P; accelerates at the rate of 2 m/s^2, and reaches its maximum speed in 10 s. It maintains this speed for 30 min and retards uniformly to rest at the station Q after the next 20 s. Calculate :

   (a) The maximum speed of the train.

   (b) Retardation

   (c) The distance between stations P and Q.

   (Ans. (a) 72 km/h, (b) 1 m/s^2 (c) 36.3 km)

3. A body travels 200 cm in the first 2 s and 220 cm in the next 5 s. Calculate the velocity at the end of the seventh second from the start. (Ans. 2.22 m/s)

4. Robbers in a car travelling at 20 m/s pass a policeman on a motorcycle at rest. The policeman immediately starts chasing the robbers. The policeman accelerates at 3 m/s^2 for 12 s and thereafter travels at a constant velocity. Calculate the distance covered by the policeman before he overtakes the car. (Ans. 270 m)

5. Interpret the velocity-time graphs (Figs. 1.16 and 1.17). (Ans. No. acceleration; uniform acceleration)

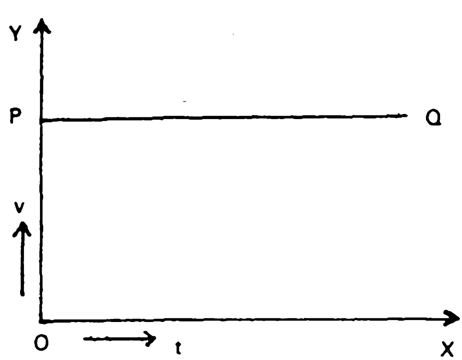


Fig. 1.16

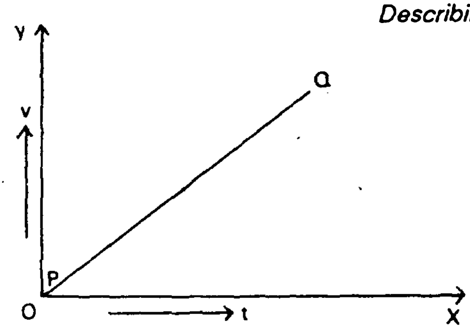


Fig. 1.17

6. In Fig. 1.18 the position of a body at different times is shown. Calculate the speed of the body as it moves from A to B, B to C and C to D. (Ans. 1 cm/s; 0; 2 cm/s)

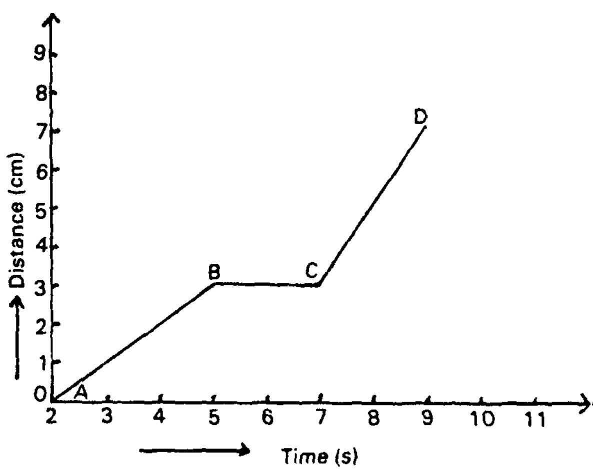


Fig. 1.18

7. A body is coming down an inclined plane with an acceleration of 1 m/s^2. If it starts from rest, find the time after which its velocity becomes 5 m/s. (Ans. 5 s)

8. The motion of a moving train has been depicted in Fig. 1.19. Find
   (a) The average velocity of the train in time OA.
   (b) The total distance covered by the train from O to B.
   (c) The uniform acceleration and retardation of the train.
   (Ans. 6 m/s; 1860 m; 6 m/s^2, –5 m/s^2)

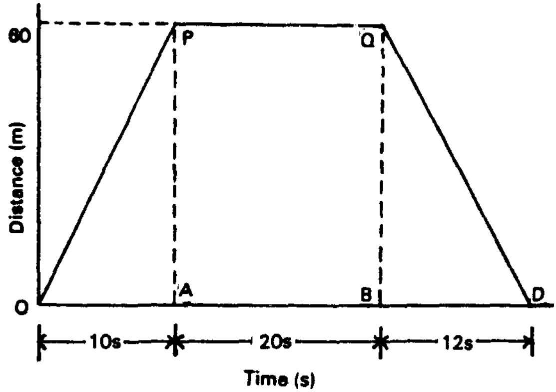


Fig. 1.19

9. A body is dropped from a balloon which is moving upward with a speed of 10 m/s. The body is dropped when the balloon is at a height of 390 m from the surface of the earth. Find the approximate time taken by the body to reach the surface of the earth. Take $g = 10\ \text{m/s}^2$. (Ans. 10 s)

10. If a force of 15 N acts on a body in the direction of north and another force of 10 N simultaneously acts on it in the direction of south, what is the resultant force acting on the body? (Ans. 5 N towards north)

11. A body is moving with a uniform acceleration, and describes 75 m in the 6th second and 115 m in the 11th second. Show that it moves 155 m during the 16th second.

12. (a) A body is dropped from the roof of a building 10 m high. Calculate the time of fall, and the speed with which it hits the ground. Take $g = 10\ \text{m/s}^2$. (Ans. 1. 4 s; 14 m/s)

    (b) A ball is thrown vertically upwards with a velocity of 20 m/s. How high did the ball go? Take $g = 9.8\ \text{m/s}^2$. (Ans. 20.4 m)

13. A bicycle moving with a velocity of 3 m/s speeds up with an acceleration of $0.5\ \text{m/s}^2$. What will its velocity be after 5 s and how far will it have moved during this time. (Ans. 5.6 m/s, 21.25 m)

14. A ball is thrown vertically upwards. It reaches its maximum height in 2.5 s. If the acceleration of the ball $10\ \text{m/s}^2$ be directed towards the ground, find the initial velocity of the ball. (Ans. 25 m/s)

15. A scooterist is racing at a speed of 72 km/h. If the radius of the wheel is 20 cm, find the angular speed of the wheels.

(Ans. 100 rad/s)

16. A wooden slab, starting from rest, slides down an inclined plane of length 10 m with an acceleration of 5 m/s. What would be its speed at the bottom of the inclined plane?

Hint : $S = \frac{1}{2} \times a \times t^2$

$10 = \frac{1}{2} \times 5 \times t^2$

$t = 2$ Sec.

$v = 0 + at$

$= 5 \times 2 = 10$ m/s

17. A train starting from rest and moving with a uniform acceleration attains a speed of 90 km/h in 5 min. Find (a) the acceleration and (b) the distance traversed.

Hint : $u = 0$

$v = \frac{90 \times 1000}{3600} = 25$ m/s

$t = 300$ s

$a = \frac{v}{t} = \frac{25}{300} = \frac{1}{12}$ m/s^2

$S = \frac{1}{2}at^2$

$= \frac{1}{2} \times \frac{1}{12} \times \frac{300 \times 300}{1000}$ km

$= 3.75$ km

18. A person rows his boat in a stream with a speed of 2.0 m/s. Water in the stream is flowing perpendicular to the direction of flow, find graphically his resultant velocity. (Ans. 2.5 m/s)

19. A bus starting from rest moves with a uniform acceleration of 0.1 m/s^2 for 2 min. Find (a) the speed acquired and (b) the distance travelled.

Hint : $u = 0$

$a = 0.1$ m/s^2

$t = 60 \times 2$ s

$v = at = 12$ m/s

$$S = \frac{1}{2}at^2 = 720 \text{ m}$$

20. A train is travelling at 90 km/h. The brakes are applied so as to produce a uniform acceleration of – 0.5 m/s^2. Find how far the train goes before it stops?

Hint : $a = -\ 0.5 \text{ m/s}^2$

$$u = \frac{90 \times 1000}{3600} = 25 \text{ m/s}$$

$$v = 0$$

$$S = ? = \frac{v^2 - u^2}{2 \times a}$$

$$S = \frac{0^2 - (25)^2}{2 \times (-0.5)}$$

or $$S = \frac{625}{2 \times ½} = 625 \text{ m}$$

21. Find the initial velocity of a train which is stopped in 20 s by applying brakes. The retardation due to brakes 1.5 m/s^2.

Hint : $u = ?$

$$t = 20 \text{ s}$$

$$v = 0$$

$$a = -\ 1.5 \text{ m/s}$$

$$v = u + at$$

$$0 = u - 1.5 \times 20$$

$$= u - 30$$

$\therefore$ $$u = 30 \text{ m/s}$$

22. A bullet leaves the barrel of a rifle with a speed of 300 m/s. If the length of the barrel is 0.9 m, at what rate is the bullet accelerated while in the barrel? (Ans. 5×10^4 m/s^2)

23. A marble is rolling at the rate of 1 m. What was the average retardation applied to the marble and how long did it take to stop the marble ? (Ans. 0.5 m/s^2, 2 s)

24. An object of mass 0.5 kg is whirled at the end of a string 0.8 m long. If the string makes three revolutions in 1.2 s, find the tension in the string. (Ans 35.6 N)

25. A body starts from rest and is found to cover 3 m during the 5th second of its motion. Find the acceleration if it is uniformly accelerated. (Ans. 0.67 m/s^2)

26. An aeroplane, taking off from a field, has a run of 500 m. What is the acceleration if it leaves the ground in 10 s from the start? Also find the take off velocity. (Ans. 10 m/s^2, 100 m/s)

27. A train 50 m long passes over a bridge 250 m long at a velocity of 30 km/h. How long will it take to completely pass over the bridge? (Ans. 36 s)

28. A cyclist goes uphill at a speed of 8 km/h and downhill at a speed of 32 km/h. If the uphill and downhill journeys involve the same distance, what is his average speed during the whole journey. (Ans. 12.8 km/h)

OBJECTIVE EVALUATION

1. Unit of acceleration is

(a) m/s (c) m s
(b) m/s^2 (d) none of these

2. A body goes from A to B with a velocity of 20 m/s and comes back from B to A with a velocity of 30 m/s. The average velocity of the body during the whole journey is

(a) zero (c) 24 m/s
(b) 25 m/s (d) none of these

3. A body covers half the distance with a speed of 20 m/s and the other half with a speed of 30 m/s. The average speed of the body during the whole journey is

(a) zero (c) 24 m/s
(b) 25 m/s (d) none of these

4. In the equation of motion $S = ut = ½ at^2$. S stands for

(a) distance in t seconds
(b) maximum height reached
(c) distance in the tth second
(d) none of these

5. Choose the wrong statement:

(a) Retardation is a vector quantity
(b) Acceleration due to gravity is a vector quantity
(c) Average speed is a vector quantity
(d) Displacement is a vector quantity

6. In the equation of motion, $x = at + bt^2$, the units of a and b are

(a) m/s^2, m/s
(b) m/s, m/s^2
(c) m/s, m/s
(d) none of these

7. A body is thrown up with an initial velocity u and covers a maximum height of h, then h is equal to
(a) $\frac{u^2}{2g}$
(b) $\frac{u}{2g}$
(c) $2\,ug$
(d) none of these

8. The seconds hand of a watch is 2 cm long. The speed of the tip of this hand is
(a) 0.21 cm/s
(b) 2.1 cm/s
(c) 21.0 cm/s
(d) none of these

9. A body is thrown vertically upwards and rises to a height of 10 m. The velocity with which the body was thrown upwards is ($g = 9.8\ m/s^2$)
(a) 10 m/s
(b) 20 m/s
(c) 14 m/s
(d) none of these

10. In problem no. 9, the time taken by the body to reach the highest point is
(a) 1.43 s
(b) 4.1 s
(c) 1.24 s
(d) none of these

11. If the time-displacement graph of a particle is parallel to the time axis, the velocity of the particle is
(a) infinity
(b) unity
(c) equal to acceleration of the body
(d) zero

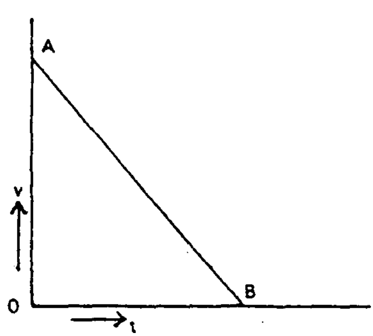


Fig. 1.20

12. Velocity-time graph AB (Fig. 1.20) shows that the body has
    (a) a uniform acceleration
    (b) a uniform retardation
    (c) uniform speed
    (d) initial velocity OA and is moving with uniform retardation

13. Velocity-time graph AB (Fig. 1.21) shows that the body has
    (a) uniform acceleration
    (b) uniform retardation
    (c) uniform velocity throughout its motion and has zero initial velocity
    (d) none of these

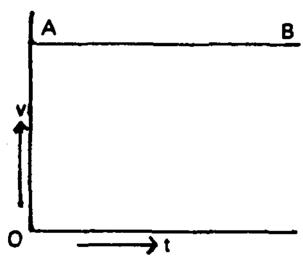


Fig. 1.21

14. The distance travelled by a freely falling body is proportional to
    (a) the mass of the body
    (b) the square of the acceleration due to gravity
    (c) the square of the time of fall
    (d) the time of fall

15. The rate of change of displacement with time is
    (a) speed
    (b) acceleration
    (c) retardation
    (d) velocity

16. A body strikes the floor vertically with a velocity u and rebounds at the same speed. The change in velocity would be
    (a) u
    (b) $2u$
    (c) $3u$
    (d) zero

17. The moon is 4×10^8 m from the earth. A radar signal transmitted from the earth will reach the moon in about

(a) 5.2 s (c) 2.6 s

(b) 1.3 s (d) 0.70 s

18. A and B are arguing about uniform acceleration. A states that acceleration means "the longer you go." B states that acceleration means "the further you go." who is right?

(a) A (c) both

(b) B (d) none

19. A particle experiences constant acceleration for 20 s after starting from rest. If it travels a distance X_1, in the first 10 s and distance X_2, in the remaining 10 s, then which of the following is true ?

(a) $X_1 = 2X_2$ (c) $X_1 = 3X_2$

(b) $X_1 = X_2$ (d) none of these

20. If a trolley starts from rest with an acceleration of 2 m/s^2, the velocity of the body after 4 s would be

(a) 2 m/s (c) 8 m/s^2

(b) 8 m/s (d) 6 m/s

21. A train passes over a 400 m long bridge. If the speed of the train is 30 m/s and the train takes 20 s to cross the bridge, find the length of the train.

(a) 400 m (c) 800 m

(b) 600 m (d) 200 m

22. The SI unit for the average velocity is

(a) m/s (c) cm/s

(b) km/s (d) mm/s

23. The SI unit for the resultant velocity is

(a) m/s (c) cm/s

(b) km/s (d) mm/s

24. A train 50 m long passes over a bridge at a velocity of 30 km/h. If it takes 36 s to cross the bridge, the length of the bridge will be

(a) 100 m (c) 250 m

(b) 200 m (d) 300 m

25. The SI unit for angular velocity is
    (a) m/s (c) rad/s
    (b) rad (c) m/rad

26. N kg^{-1} is the unit of
    (a) retardation (c) rate of change of velocity
    (b) acceleration (d) all the above

27. A ball is thrown up with a certain velocity. It attains a height of 40 m and comes back to the thrower. The
    (a) total distance covered by it is 40 m
    (b) total displacement covered by it is 80 m
    (c) total displacement is zero
    (d) total distance covered by it is zero

28. The acceleration of a body projected upwards with a certain velocity is
    (a) 9.8 m/s^2 (c) zero
    (b) – 9.8 m/s^2 (d) insufficient data

29. A driver is driving his car along a road is shown in Fig. 1.22. The driver makes sure that the speedometer reads exactly 40 km/h. What happens to the speed of the car from P to Q ?

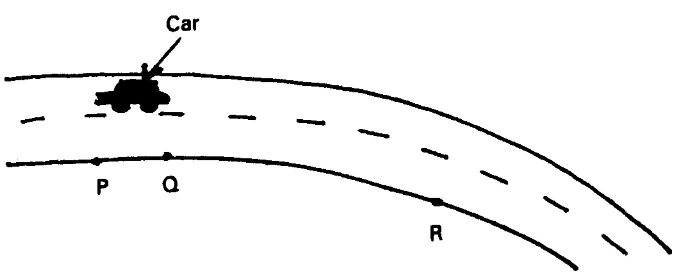


Fig. 1.22

(a) speed remains constant
(b) speed first increases then decreases
(c) speed first decreases then increases
(d) nothing can be decided

30. In the above question, what happens to the velocity of the car from P to Q ?
    (a) velocity remains constant
    (b) velocity first increases then decreases
    (c) velocity first decreases then increases
    (d) nothing can be decided
31. In Question 29, the driver should say that
    (a) the average speed is 40 km/h
    (b) the average velocity is 40 km/h
    (c) the average speed is 80 km/h
    (d) the average velocity is 80 km/h
32. A stone tied to a string is whirled in a circle. As it is revolving, the rope suddenly breaks. Then
    (a) the stone flies off tangentially
    (b) the stone moves radially inward
    (c) the stone moves radially outward
    (d) the motion of the stone depends upon its velocity
33. In the following graph (Fig. 1.23) of displacement versus time,
    (a) the body is at rest
    (b) the body has some initial speed
    (c) the body moves with constant speed
    (d) the body moves with constant velocity

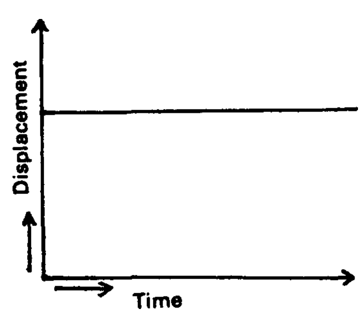


Fig. 1.23

34. Figure 1.24 shows the displacement-time graphs (a) and (b) for a body moving in a straight path drawn on the same scales. Then

(a) slope of line in (a) is greater than the slope of line in (b)

(b) slope of line in (b) is greater than the slope of line in (a)

(c) slope of line in (a) is equal to the slope of line in (b)

(d) nothing can be said about the slopes

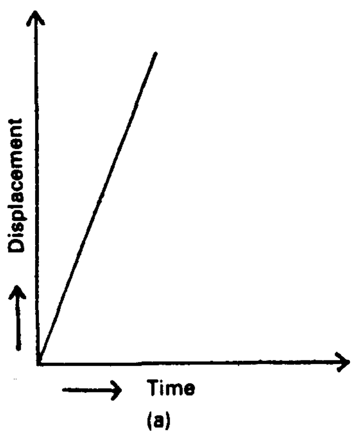


Fig 1.24 (a)

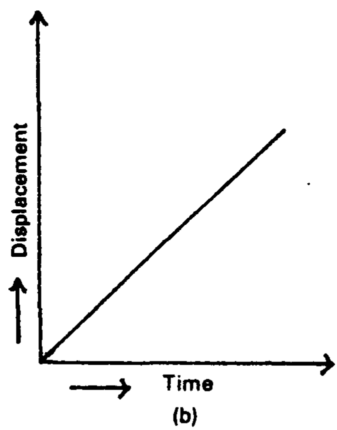


Fig 1.24 (b)

35. It follows from Question 34, that the velocity in case of (b) is

(a) more than the velocity in case of (a)

(b) less than the velocity in case of (a)

(c) equal to the velocity in case of (a)

(d) square of the velocity in case of (a)

36. In Fig. 1.25, BC represents a body moving

(a) backward with uniform velocity

(b) forward with uniform velocity

(c) backward with non-uniform velocity

(d) forward with non-uniform velocity

37. In Fig. 1.26 the velocity of the body at A is

(a) zero

(b) unity

(c) maximum

(d) infinite

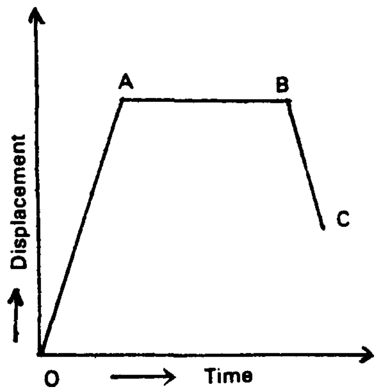


Fig. 1.25

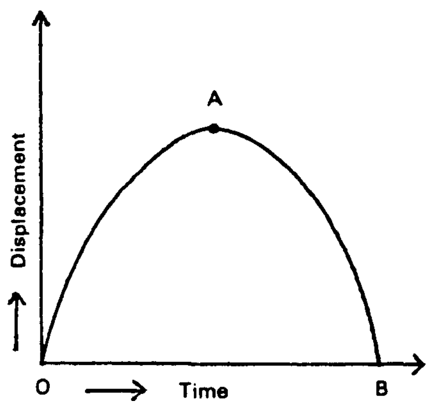


Fig. 1.26

38. In the above question, the velocity
    (a) increases between point O and A
    (b) increases between point A and B
    (c) decreases between points A and B
    (d) is zero throughout

39. A body moving along a circular path has
    (a) a constant speed
    (b) a constant velocity
    (c) no tangential velocity
    (d) no radial acceleration

40. In Fig. 1.27

(a) retardation is uniform

(b) velocity is decreasing with time

(c) beyond M, the body has negative velocity

(d) all the above are correct

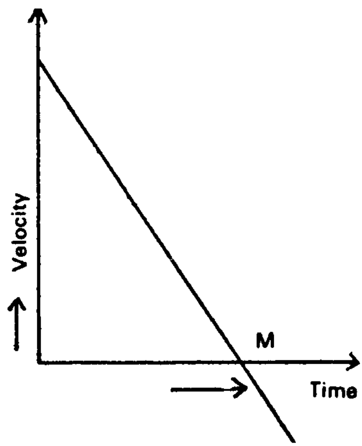


Fig. 1.27

41. P is moving in a straight line with uniform velocity. Q is moving in a straight line with steadily increasing velocity.

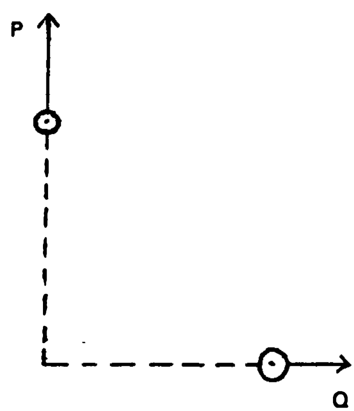


Fig. 1.28

Which of the following (Fig. 1.29) shows, Q's apparent path w.r.t. P ?

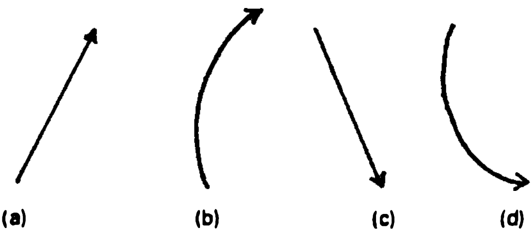


Fig. 1.29

(a) A (c) C

(b) B (d) D

42. The velocity of a particle increases from u to v in a time t during which it covers a distance S. If the particle has an uniform acceleration, which one of the following equations does not apply to the motion?

(a) $2\,S = (v + u)\,t$ (c) $v^2 = u^2 - 2\,aS$

(b) $a = \dfrac{v - u}{t}$ (d) $S = (u + \dfrac{1}{2}at)\,t$

43. Which of the following (Fig. 1.31) would probably show the velocity-time graph for a body whose acceleration-time graph is shown in Fig. 1.30.

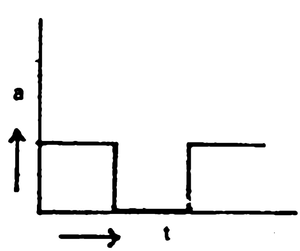


Fig. 1.30

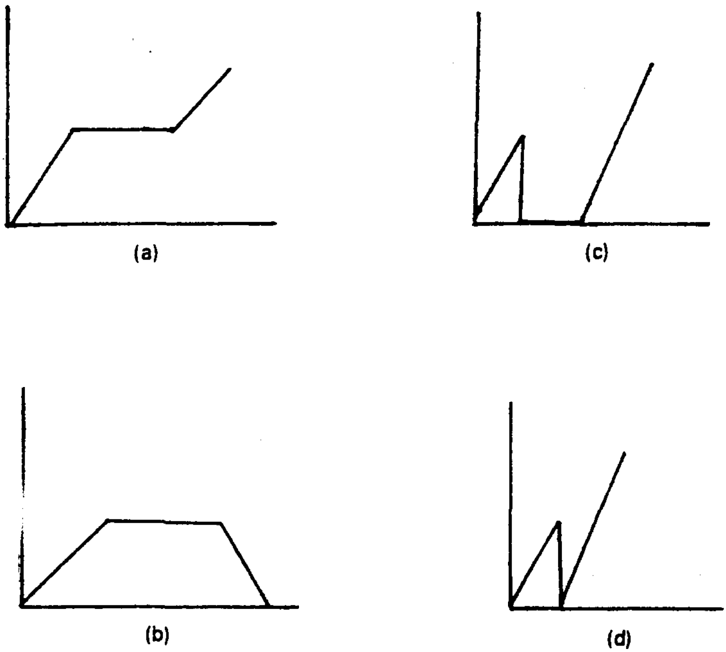


Fig. 1.31

(a) A (c) C
(b) B (d) D

44. The velocity-time graph of a body falling from rest under gravity and rebounding from a solid surface is represented by which of the graphs shown in Fig. 1.32.
(a) a (c) c
(b) b (d) d

45. The unit for the rate of change of velocity will be
(a) m/s (c) N – s
(b) m/s^2 (d) N/s

46. The acceleration-time graph for a body is shown in Fig. 1.33. The most probable velocity-time graph (Fig. 1.34) for the body is

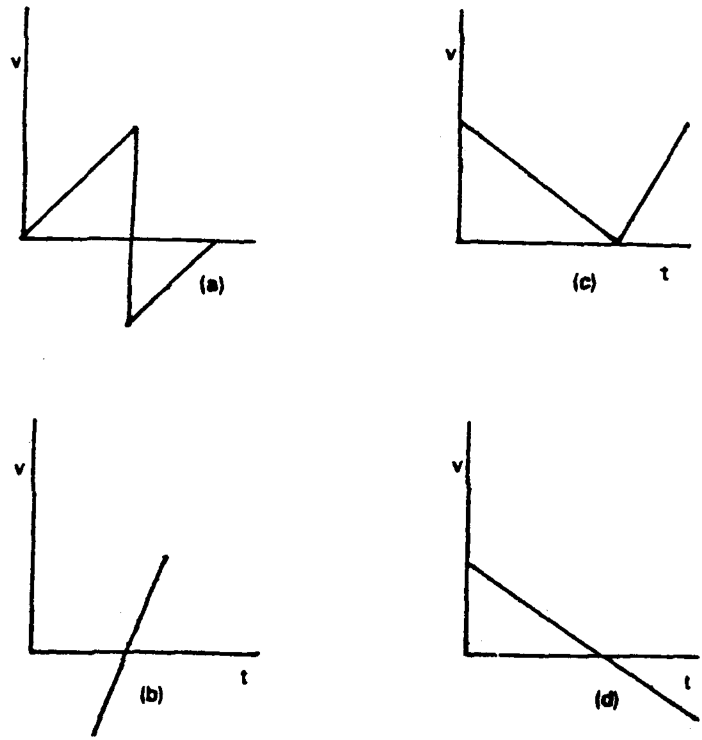


Fig. 1.32

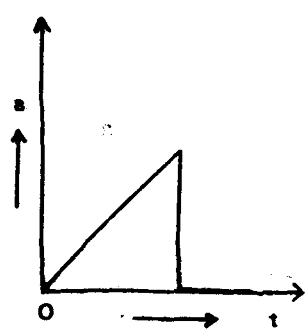


Fig. 1.33

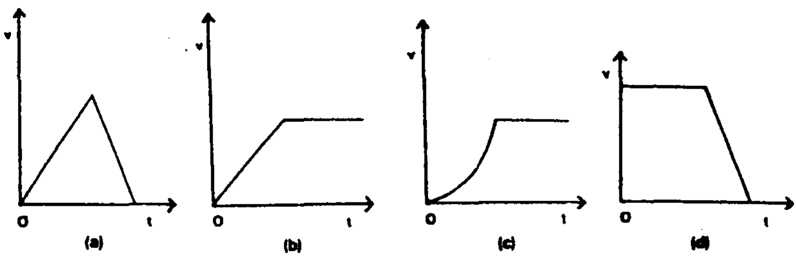


Fig. 1.34

(a) a

(b) b

(c) c

(d) d

47. A cyclist moves from a certain point X and goes round a circle of radius 'r' and reaches at Y, exactly at the other side of the point X, as shown in Fig. 1.35. The displacement of the cyclist would be

(a) πr

(b) $2\pi r$

(c) $2r$

(d) $2\pi / r$

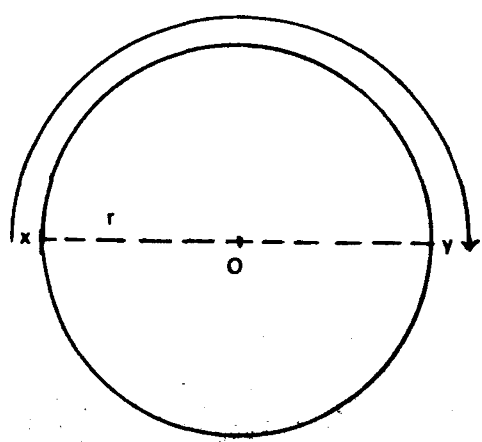


Fig. 1.35

48. In the above problem, the distance covered by the cyclist would be

(a) πr (c) $2r$

(b) $2\pi r$ (d) $2\pi / r$

49. Which of the following relations represent the relationship between the average speed, time and distance correctly ?

(a) Average speed = distance × time

(b) Average speed = $\dfrac{\text{total distance}}{\text{total time}}$

(c) Time = average speed/distance

(d) Distance = average speed × time

50. When a graph between two physical quantities is a straight line, the two quantities are:

(a) both constant (c) directly proportional

(b) independent (d) inversely proportional

51. A body moving along a circular path, has

(a) constant speed (c) no radial acceleration

(b) constant velocity (d) no tangential velocity

52. Area under a velocity-time graph gives

(a) the time taken by a moving object

(b) the distance travelled by a moving object

(c) the acceleration of moving object

(d) the retardation of a moving object

53. When the distance an object travels is directly proportional to the length of time, it is said to travel with

(a) constant speed (c) constant acceleration

(b) zero velocity (d) uniform velocity

True or False Statements

1. The distance travelled by a body starting from rest and moving with uniform acceleration is directly proportional to the square of the time.

2. Motion of an object moving in a circle with constant speed is an example of accelerated motion.

3. The graph between velocity and time for uniform acceleration is a curved line.

4. If acceleration is zero, the velocity is also zero.
5. Speed can be uniform even if velocity is not uniform.
6. SI unit of angular velocity is rad/s.
7. When a body starts moving from rest its initial velocity is zero.
8. A body moves from P to Q with a certain velocity and returns from Q to P with the same velocity. Its average velocity during the whole journey is zero.
9. Speed is a fundamental physical quantity.
10. SI unit for velocity is m/s.
11. SI unit for retardation is m/s^2.
12. Vector quantities are those which are completely described by magnitude alone.
13. Whenever a moving body is brought to rest its acceleration is always zero.
14. If a body goes from a certain point and comes back to the same point, its displacement is zero.
15. Average speed $= \frac{\text{Total distance}}{\text{Total time}}$
16. The velocity of a body moving in a circle remains constant.
17. The distance travelled by a body, moving with uniform acceleration, is directly proportional to time.
18. The change of position of an object is called distance.
19. The units of speed and velocity are different.
20. Negative acceleration is called retardation.

ANSWERS (OBJECTIVE EVALUATION)

1. (b)	2. (a)	3. (c)	4. (a)	5. (c)	6. (b)	7. (a)	8. (a)	9. (c)
10. (a)	11. (d)	12. (d)	13. (d)	14. (c)	15. (d)	16. (d)	17. (b)	18. (c)
19. (d)	20. (b)	21. (d)	22. (a)	23. (a)	24. (c)	25. (c)	26. (d)	27. (c)
28. (b)	29. (a)	30. (a)	31. (a)	32. (a)	33. (a)	34. (a)	35. (b)	36. (a)
37. (a)	38. (b)	39. (a)	40. (d)	41. (d)	42. (c)	43. (a)	44. (a)	45. (b)
46. (c)	47. (a)	48. (b)	49. (b)	50. (c)	51. (a)	52. (b)	53. (a)	

ANSWERS (TRUE OR FALSE)

1. T	2. T	3. F	4. F	5. T	6. T	7. T	8. F	9. F
10. T	11. T	12. F	13. F	14. T	15. T	16. F	17. F	18. F
19. F	20. T							

UNIT TWO
FORCE AND ACCELERATION

REVIEW CONCEPTS

Force is that agency which can, change the state of rest or of uniform motion or shape or direction of motion of anybody. The unit of force in mks system is Newton. It is a vector quantity.

Balanced and Unbalanced Forces

(a) *Balanced forces* cannot change the speed of a body. They can change the shape of the object. If the resultant of the forces acting on a body is zero, the forces are said to be balanced.

(b) *Unbalanced forces* can cause the change in speed or direction of motion of the body. If the resultant of the forces acting on the body is not zero, the forces are said to be unbalanced.

Resultant force : When two or more forces act on a body simultaneously, then the single force which produces the same effect as produced by all the forces acting together, is known as the resultant force.

Inertia is the property of a body due to which the body opposes any change in its state of rest or of uniform motion along a straight line. Inertia is the measure of mass. More mass means more inertia.

Newton's first law of motion : Every body remains in its state of rest or of uniform motion unless it is compelled to change its state by an unbalanced force impressed on it.

Newton's second law of motion : The rate of change of momentum of a body is directly proportional to the unbalanced force applied and takes place in the direction of the force.

Newton's third law of motion : To every action there exists an equal and opposite reaction. Action and reaction always act on different bodies.

Momentum : The product of the mass of a body and its velocity is called the momentum of the body. It is a vector quantity.

It is the measure of the quantity of the motion possessed by a body.

Impulse : The product of force and time for which it is applied is called impulse. SI unit of impulse is Ns.

Law of conservation of momentum : The total momentum of a system remains constant unless some external force acts on it.

Frictional force is due to irregularities on the surface which opposes the motion of an object over another body in contact with it. Without friction we cannot even walk. But in some cases we need to reduce friction for smooth working of the system. In the case of solid surfaces the force of friction is more as compared to two liquid surfaces. Lubricants are used to reduce friction.

Formula Force $(F) = m \times a$

where, F = force

m = mass

a = acceleration

Also, $m = F/a$ or $a = F/m$

Momentum $p = m\text{v}$

where, p = momentum

m = mass

v = speed

Also,

Change in momentum $= m$ (change in velocity)

$= m(v - u)$

where, v = final velocity

u = initial velocity

Impulse $= F \times t$

where, F = force and

t = time for which force is applied

Conservation of momentum

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

where, m_1 = mass of the first body

m_2 = mass of the second body

u_1 = initial speed of first body

u_2 = initial speed of second body

v_1 = final speed of first body and

v_2 = final speed of second body

Also,

Force = rate of change of momentum

$$F = \frac{p_2 - p_1}{t}$$

where, p_2 = final momentum

p_1 = initial momentum and

t = time

Also, $$F = \frac{m(v - u)}{t}$$

or $$F \times t = m(v - u)$$

Impulse $= F \times t$

Impulse $= m(v - u)$

= change in momentum

From Newton's third law,

$$F_1 = -F_2$$

where F_1 = force of action and

F_2 = force of reaction

Also, $$\frac{m_1(v_1 - u_1)}{t} = -\frac{m_2(v_2 - u_2)}{t}$$

$$m_1a_1 = -m_2a_2$$

or $$F_{12} = -F_{21}$$

NUMERICAL PROBLEMS (SOLVED)

EXAMPLE 1 Which would require a greater force — accelerating a 10 g mass at 5 m/s^2 or 20 g mass at 2 m/s^2 ?

Solution: Given,

Mass of the body A (m_1) = 10 g = 10×10^{-3} kg

Mass of the body B (m_2) = 20 g = 20×10^{-3} kg

Acceleration of body A (a_1) = 5 m/s^2

Acceleration of body B (a_2) = 2 m/s^2

To calculate : Force F_A and F_B and comparing them

Formula to be used : $F = ma$

(i) Force for body A $(F_A) = m_1a_1 = (10 \times 10^{-3})\ (5)$

$$F_A = \frac{5}{100} = 0.05 \text{ N}$$

(ii) Force for body B $(F_B) = m\,a = (20 \times 10^{-3})\ (2)$

$$F_B = \frac{4}{100} = 0.04 \text{ N}$$

since $F_A > F_B$, $\therefore$ we need more force to accelerate A of mass 10 g.

EXAMPLE 2 What is the acceleration produced by a force of 12 N exerted on an object of mass 3 kg?

Solution: Given,

Force (F) = 12 N

Mass (m) = 3 kg

To calculate : Acceleration (a) = ?

Formula to be used : $F = ma$

$\Rightarrow a = F/m$

Substituting the values of 'F' and 'm', we get

$$a = 12/3 = 4 \text{ m/s}$$

EXAMPLE 3 What force would be needed to produce an acceleration of 4.0 m/s^2 on a ball of mass 6 kg?

Solution: Given,

Acceleration (a) = 4 m/s^2

Mass (F) = 6 kg

To calculate : Force (F) = ?

Formula to be used : $F = m \times a$

Substituting the given values of 'm' and 'a,' we get

$$F = 6 \times 4 = 24 \text{ N}$$

EXAMPLE 4 An object undergoes an acceleration of 8.0 m/s^2 starting from rest. Find the distance travelled in one second.

Solution: Given,

Acceleration (a) = 8.0 m/s^2

Initial speed (u) = 0

Time (t) = 1s

To calculate : Distance (d) = ?

Formula to be used : $d = ut + \frac{1}{2}at^2$

$$d = (0 \times 1) + \left(\frac{1}{2} \times 8 \times (1)^2\right)$$

$$= 0 + 4$$

$$d = 4 \text{ m}$$

EXAMPLE 5 A truck starts from rest and rolls down a hill with constant acceleration. It travels a distance of 400 m in 20 s. Find its acceleration. Find the force acting on it if its mass is 7 metric tonnes.

Solution: Given,

Distance (d) = 400 m
Initial speed (u) = 0
Time (t) = 20 s
Mass (m) = 7 metric tonnes
= 7000 kg

To calculate : (i) acceleration (a) = ?
(ii) Force (F) = ?

Formula to be used (i) $d = ut + \frac{1}{2}at^2$

(ii) $F = m \times a$

(i) To find acceleration

$$d = ut + \frac{1}{2}at^2$$

$$400 = (0 \times 20) + \frac{1}{2}(a)\ (20)^2$$

$$400 = 0 + \frac{1}{2}(a) \times 400$$

$$400 = 200\,a \quad \Rightarrow \quad a = 2\ \text{m/s}^2$$

(ii) To calculate force

$$F = m \times a$$

$$= 7000 \times 2 = 14000\ \text{N}$$

EXAMPLE 6 A certain force exerted for 1.2 s raises the speed of an object from 1.8 m/s to 4.2 m/s. Later this same force is applied for 2.0 s. By how much does the speed change in 2.0 s?

Solution: Given,

Initial speed (u) = 1.8 m/s
Final speed (v) = 4.2 m/s
Time (t) = 1.2 s
Time (t) = 2.0 s

To calculate : Change in speed $(v - u)$ = ?

Formula to be used : (i) $a = \frac{v - u}{t}$

Substituting the values of v, u and t, we get

$$a = \frac{4.2 - 1.8}{1.2} = \frac{2.4}{1.2} = 2 \text{ m/s}^2$$

Let 'F' be the force which produces this acceleration $a = 2.0 \text{ m/s}^2$.
Now the force 'F' is acting on the body for $t = 2.0$ s

$$\therefore \quad v - u = a \times t$$

$$v - u = 2 \times 2$$

$$v - u = 4 \text{ m/s}$$

EXAMPLE 7 Two blocks made of different metals identical in shape and size are acted upon by equal forces which cause them to slide on a horizontal surface. The acceleration of the second block is found to be 5 times that of the first, what is the ratio of the mass of the second to the first ?

Solution: Given,

$$\frac{\text{Acceleration of the first block } (a_1)}{\text{Acceleration of the second block } (a_2)} = \frac{1}{5}$$

Force (F) = F (same on both the blocks)

To calculate : $\frac{m_2}{m_1} = ?$

Formula to be used : $F = ma$

Now, according to the given condition,

$$F = m_1 a_1 \text{ and } F = m_2 a_2$$

$$\therefore \quad a_1 = \frac{F}{m_1} \text{ and } a_2 = \frac{F}{m_2}$$

But,

$$\frac{a_1}{a_2} = \frac{1}{5}$$

$$\frac{F/m_1}{F/m_2} = \frac{1}{5}$$

or

$$\frac{m_2}{m_1} = \frac{1}{5}$$

The ratio of the mass of the second block to the first block is 1 : 5.

EXAMPLE 8 A force of 5.0 N gives a mass (m_1), an acceleration of 8.0 m/s^2 and a mass (m_2), an acceleration of 24 m/s^2. What acceleration would it give if the both the masses are tied together ?

Solution: Given,

Force (F) = 5.0 N

Acceleration of the first body (a_1) = 8.0 m/s^2

Acceleration of the second body (a_2) = 24 m/s^2

To calculate :

Acceleration (a) for a body of mass ($m_1 + m_2$) = ?

Formula to be used : $F = m \times a$

Our first problem is to find m_1 and m_2

Therefore using $m_1 = \dfrac{F}{a_1}$ and $m_2 = \dfrac{F}{a_2}$

$$m_1 = \frac{5}{8}\text{ kg} \quad \text{and} \quad m_2 = \frac{5}{24}\text{ kg}$$

$$\therefore \qquad m_2 = m_1 + m_2$$

$$= \frac{5}{8} + \frac{5}{24}$$

$$= \frac{15 + 5}{24} = \frac{20}{24}\text{ kg}$$

Hence,

$$a = \frac{F}{m} = \frac{5}{20/24}$$

$$a = \frac{5 \times 24}{20} = \frac{120}{20} = 6.0 \text{ m/s}^2$$

EXAMPLE 9 A motorcycle accelerates uniformly from 10 m/s to 20 m/s in 12.0 s. Calculate (i) acceleration and (ii) the distance covered.

Solution: Given,

Initial speed (u) = 10 m/s

Final speed (v) = 20 m/s

Time (t) = 12.0 s

To calculate : (i) Acceleration (a) = ?

(ii) Distance (d) = ?

Formula to be used : (i) $a = \dfrac{v - u}{t}$ and

(ii) $d = ut + \dfrac{1}{2}at^2$

To find (a)

$$a = \frac{v - u}{t} = \frac{20 - 10}{12}$$

$$a = \frac{10}{12} = \frac{5}{6}\ \text{m/s}^2$$

To calculate (d)

$$d = ut + \frac{1}{2}at^2$$

$$= (10 \times 12) + \frac{1}{2} \times \left(\frac{5}{6}\right)(12)^2$$

$$= 120 + \frac{1}{2} \times \frac{5}{6} \times 144$$

$$= 120 + (5 \times 12)$$

$$= 120 + 60 = 180\ \text{m}$$

EXAMPLE 10 A truck accelerates at a constant rate of change of velocity in 5.0 s from 10 m/s to 25 m/s on a high way. What is the acceleration and how far does the truck go in this interval of time ? Give a graphical solution.

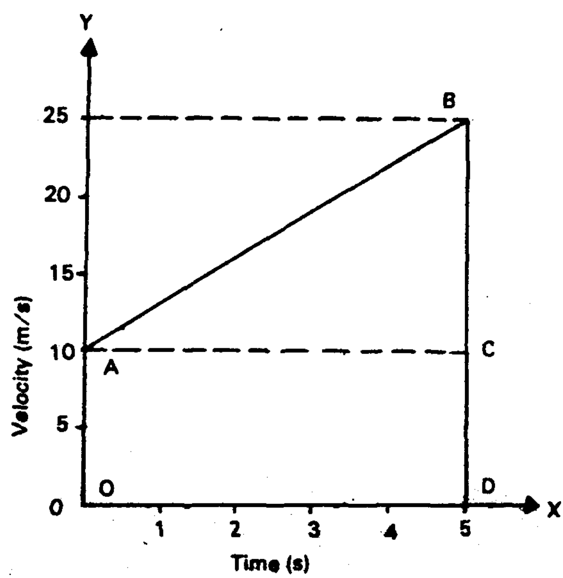


Fig. 2.1

Solution: Given,

Time (t) = 5.0 s

Initial speed (u) = 10 m/s

Final speed (v) = 25 m/s

To calculate : (i) Acceleration (a) = ?

(ii) Distance (d) = ?

Formula to be used : (i) Acceleration (a) = $\frac{\text{change in velocity}}{\text{time}}$

(ii) Distance (d) = Area under the velocity-time graph

(i) To calculate (a) : From the graph

$$a = \frac{BC}{AC} = \frac{15}{5}$$

$$a = 3.0 \text{ m/s}^2$$

(ii) Distance (d) : Area under the graph OABCD

= Area of the rectangle OACD + Area of the triangle ABC

$$= (10 \times 5) + \frac{1}{2} \times 5 \times 15$$

$$= 50 + \frac{75}{2}$$

$$d = \frac{100 + 75}{2} = 87.5 \text{ m}$$

EXAMPLE 11 Calculate the force required to impart a velocity of 30 m/s in 10.0 s to a car. The mass of the car is 1500 kg.

Solution: Given,

Initial velocity (u) = 0 (since the car starts from rest)

Final velocity (v) = 30 m/s

Time (t) = 10 s

Mass (m) = 1500 kg

To calculate : Force (F) = ?

Formula to be used : $F = ma$

or $$F = \frac{m\,(v - u)}{t}$$

Substituting the values of m, v, u and t

$$F = \frac{1500\,(30 - 0)}{10}$$

$$= \frac{1500 \times 30}{10}$$

$$= 4500 \text{ N}$$

EXAMPLE 12 A body of mass 5.0 kg is moving with a uniform velocity of 10 m/s. It is acted upon by a force of 20 N. What will be its velocity after 1.0 s ?

Solution: Given,

Mass (m) = 5.0 kg
Initial velocity (u) = 10 m/s
Force (F) = 20 N
Time (t) = 1.0 s

To calculate : Final velocity (v) = ?

Formula to be used : $v = u + at$ (i)

But we do not know the value of a. Therefore using the formula, $F = ma$, we can write

$$a = F/m$$

By substituting $a = F/m$ in equation (i) we get

$$v = u + (F/m \times t)$$

$$= 10 + \left(\frac{20}{5} \times 1\right) = 10 + 4$$

$$v = 14 \text{ m/s}$$

EXAMPLE 13 In order to gain a velocity of 12.0 m/s, how long should a force of 30 N be exerted on a body of mass 5.0 kg ?

Solution: Given,

Change in velocity ($v - u$) = 12 m/s
Force (F) = 30 N
Mass (m) = 5.0 kg

To calculate : Time (t) = ?

Formula to be used : $F = \dfrac{m(v - u)}{t}$

=> $t = \dfrac{m(v - u)}{F}$

$$t = \frac{5\ (12)}{30} = \frac{60}{30} = 2.0 \text{ s}$$

EXAMPLE 14 The velocity of a body of mass 5.0 kg reduces from 10 m/s to 5.0 m/s. What is the change in momentum of the body?

Solution: Given,

Mass (m) = 5.0 kg

Initial velocity (u) = 10 m/s

Final velocity (v) = 5.0 m/s

To calculate : Change in momentum

$\Delta p = ?$

Formula to be used : $\Delta p = mv - mu$

$\therefore \quad \Delta p = 5 \times (5) - 5 \times 10$

$\Delta p = 25 - 50 = -25$ kg m/s

EXAMPLE 15 A 5 kg rifle fires a 10 g bullet at a velocity of 500 m/s. Find the recoil velocity of the rifle.

Solution: Given,

Mass of the rifle (m_1) = 5 kg

Mass of the bullet (m_2) = 10 g = 10×10^{-3} kg

Velocity of the bullet (v_2) = 500 m/s

To calculate : Velocity of the rifle (v_1) = ?

Formula to be used : $m_1 v_1 = m_2 v_2$

$$5 \times v_1 = (10 \times 10^{-3})\ (500)$$

$$v_1 = \frac{10 \times 10 \times 500}{5}$$

$$v_1 = 1 \text{ m/s}$$

EXAMPLE 16 A block of mass 3 kg has a velocity of u m/s. When a force of 18 N acts on the block, it reduces the velocity from u to $u/2$ after the block has covered a distance of 9.0 m. Find u.

Solution: Given,

Mass (m) = 3 kg

Force (F) = 18 N

Initial velocity (u) = u m/s

Final velocity (v) = $\frac{u}{2}$ m/s

Distance (d) = 9.0 m

To calculate : Initial velocity $(u) = ?$

Formula to be used : $v^2 - u^2 = 2ad$

or $$v^2 - u^2 = 2 \times \frac{F}{m} \times d$$

$$(\because \; a = F/m)$$

The value of a is negative. Since final velocity is less than the initial velocity

$$\left(\frac{u}{2}\right)^2 - (u)^2 = 2 \times \left(\frac{-18}{3}\right) \times 9$$

$$\frac{u^2}{4} - u^2 = -108$$

$$u^2 - 4u^2 = -432$$

$$u = 12 \text{ m/s}$$

EXAMPLE 17 A bullet of mass 4 g when fired with a velocity of 50 m/s, can enter a wall up to a depth of 10 cm. How much will be the average resistance offered by the wall?

Solution: Given,

Mass of the bullet $(m) = 4 \text{ g} = 4 \times 10^{-3}$ kg

Initial velocity $u = 50$ m/s

Distance $(d) = 10 \text{ cm} = 10 \times 10^{-2}$ m

Final velocity $(v) = 0$ (since bullet comes to rest finally)

To calculate : Force $(F) = ?$

Formula to be used : $F = m \times a$

or $$F = m \times \left(\frac{v^2 - u^2}{2d}\right)$$

from $$v^2 - u^2 = 2ad$$

$$a = \frac{v^2 - u^2}{2d}$$

$$F = 4 \times 10^{-3} \times \left[\frac{(0)^2 - (50)^2}{2 \times (10 \times 10^{-2})}\right]$$

$$= 4 \times 10^{-3} \left[\frac{-2500 \times 10^2}{2 \times 10}\right]$$

$$F = -50 \text{ N.}$$

EXAMPLE 18 A steam engine of mass 3×10^4 kg accelerates two wagons each of mass 2×10^4 kg through $0.2\ m/s^2$. Neglecting frictional forces. Calculate

(i) the force exerted by the engine and

(ii) the force experienced by each wagon.

Solution: Given,

Mass of the engine $(m_1) = 3 \times 10^4$ kg

Mass of each wagon $(m_2) = 2 \times 10^4$ kg

Acceleration $(a) = 0.2\ m/s^2$

To calculate : (i) Force exerted by the engine (F)?

(ii) Force experienced by each wagon = ?

Formula to be used : $F = m \times a$

when force exerted by the engine is to be calculated

$$m = m_1 + 2m_2$$

(Total mass (m) = mass of the engine + mass of two wagons)

$$F = m \times a$$

$$= [(3 \times 10^4) + 2(2 \times 10^4)] \times 0.2$$

$$= (3 \times 10^4 + 4 \times 10^4) \times 0.2$$

$$F = 1.4 \times 10^4\ N$$

(iii) In the second case, we will only take the mass of one wagon

$$\therefore \quad F = m \times a$$

$$= 2 \times 10^4 \times 0.2$$

$$F = 0.4 \times 10^4\ N$$

EXAMPLE 19 A target of mass 400 g moving with a horizontal speed of 10 m/s is hit by a bullet of mass 0.01 kg moving in the opposite direction. If both the bullet and the target come to rest after collision. Calculate the velocity of the bullet at the time of striking the target.

Solution: Given,

Mass of the bullet $(m_1) = 0.01$ kg

Mass of the target $(m_2) = 400\ g = 400 \times 10^{-3}$ kg

Initial speed of the target $(u_2) = 10$ m/s

Final speed of the bullet $(v_1) = 0$ m/s

Final speed of the target $(v_2) = 0$ m/s

To calculate : Initial speed of the bullet (u_1) = ?

Formula to be used : $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$$(0.01 \times u_1) + (400 \times 10^{-3} \times 10)$$
$$= (0.01 \times 0) + (400 \times 10^{-3} \times 0)$$

or $(0.01\,u_1) + 4 = 0$

or $0.01\,u_1 = -4$

$$u_1 = \frac{-4}{0.01}$$
$$u_1 = -400 \text{ m/s}$$

The negative sign shows that direction of motion of the bullet.

EXAMPLE 20 A bullet of mass 5.0 g hitting a sand bag suspended in air gets embedded in it. If the velocity of the bullet is 900 m/s just before it hits the bag, find out the speed with which the sand bag will move due to the impact of the bullet. The mass of the sand bag is 50 kg.

Solution: Given,

Mass of the bullet (m_1) = 5.0 g = 5×10^{-3} kg

Initial velocity of the bullet (u_1) = 900 m/s

Mass of the sand bag (m_2) = 50 kg

Final velocity of the bullet (v_1) = 0 m/s

Initial velocity of the bag (u_2) = 0 m/s

To calculate : Final velocity of the bag (v_2) = ?

Formula to be used : $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$$(5 \times 10^{-3} \times 900) + (50 \times 0) = (5 \times 10^{-3} \times 0) + (50 \times v_2)$$
$$(45 \times 10^{-1}) + 0 = 0 + 50\,v_2$$

=> $$v_2 = \frac{45 \times 10^{-1}}{50} = 0.09 \text{ m/s}$$

EXAMPLE 21 A man in a circus show jumps from a height of 10 m and is caught by a net spread below him. The net sags due to his impact. Find out the average force exerted by the net on the man to stop his fall. Take the mass of the man to be 60 kg and consider the value of acceleration due to gravity during his free fall as 10 m/s^2.

Solution: Given,

Initial velocity of the man $(u) = 0$

Height $(h) = 10.0$ m

Acceleration due to gravity $(g) = 10$ m/s

Mass of the man $(m) = 60$ kg

To calculate : Average retarding force $(F) = ?$

Formula to be used : $F = m \times a$

But we do not know the value of a.

Using the formula,

$$a = \frac{v^2 - u^2}{2d}$$

we can determine a. But again we do not know v so from,

$$v^2 - u^2 = 2\,ad$$
$$v^2 = 2\,ad + u^2$$
$$v^2 = 2 \times 10 \times 10 + (0)^2$$
$$v^2 = 200 \Rightarrow v = \sqrt{200} \text{ m/s}$$

Thus this velocity becomes the initial velocity of the net. As the net moves 2.0 m down (sags), its final velocity becomes zero.

Again,

Initial speed $(u) = \sqrt{200}$ m/s

Final speed $(v) = 0$

Distance $(d) = 2.0$ m

$g = 10$ m/s

$$a = \frac{v^2 - u^2}{2d} = \frac{(0)^2 - (\sqrt{200})^2}{2 \times 2}$$

$$a = -50 \text{ m/s}^2$$

$\therefore$ Force exerted by the man $(F) = m \times a$

$= 60 \times (-50)$

$F = -300$ N

or Force exerted by the net $= +300$ N

EXAMPLE 22 A cricket ball of mass 50 g moving with a velocity of 10 m/s is brought to rest by a player in 0.02 s. Find the impulse of the force and the average force applied by the player.

Solution: Given,

Mass of the ball (m) = 50 g = 50×10^{-3} kg

Initial velocity (u) = 10 m/s

Final velocity (v) = 0 m/s

Time (t) = 0.02 s

To calculate : (i) Force (F) = ?

(ii) Impulse (I) = ?

Formula to be used : (i) $F = \dfrac{m(v - u)}{t}$

(ii) $I = F \times t$

(i) Force (F) $= \dfrac{m(v - u)}{t}$

$$= \frac{50 \times 10^{-3} (0 - 10)}{0.02}$$

$$= \frac{50 \times 10^{-3} \times (-10)}{0.02}$$

$$F = -25 \text{ N}$$

(Negative sign shows that the force is retarding)

(ii) Impulse (I) $= F \times t$

$= 25 \times 0.02$

$= 0.5$ N s

EXAMPLE 23 A bullet of mass 20 g starts from rest from one end of the barrel of a gun 1.5 m long and weighing 4.0 kg. The bullet leaves at the other end with a velocity of 350 m/s. Calculate (i) the time taken by the bullet to leave the gun and (ii) the velocity of recoil of the gun.

Solution: Given,

Mass of the bullet (m_1) = 20 g = 20×10^{-3} kg

Initial speed of the bullet (u_1) = 0

Distance (d) = 1.5 m

Mass of the gun (m_2) = 4.0 kg

Final speed of the bullet (u_2) = 350 m/s

Initial speed of the gun (u_2) = 0

To calculate : (i) Time (t) = ?

(ii) Recoil velocity (v_2) = ?

Formula to be used : (i) $t = \dfrac{v - u}{a}$

(ii) $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

Calculation of time t,

$$t = \frac{v - u}{a}$$

But $a = \dfrac{v^2 - u^2}{2d}$ for the bullet

$$= \frac{(350)^2 - (0)^2}{2 \times 1.5}$$

$$= \frac{122500}{3} \text{ m/s}^2$$

$$t = \frac{350 - 0}{122500/3} = \frac{350 \times 3}{122500}$$

$$t = 0.009 \text{ s}$$

(ii) Calculation of recoil velocity (v_2)

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

$$(20 \times 10^{-3} \times 0) + (4 \times 0) = (20 \times 10 \times 350) + (4 \times v_2)$$

$$= (20 \times 10^{-3} \times 350) = 4\,v_2$$

$$7000 \times 10^{-3} = 4v_2 \quad \text{or} \quad \frac{7}{4} = v_2$$

$$\Rightarrow \quad v_2 = 1.75 \text{ m/s}$$

EXAMPLE 24 A stationary football weighing 1.25 kg acquires a speed of 10 m/s when kicked. What is the impulse imparted to the ball?

Solution: Given,

Initial speed (u) = 0 m/s

Final speed (v) = 10 m/s

Mass of the ball (m) = 1.25 kg

To calculate : Impulse = ?

Formula to be used : Impulse = $m(v - u)$

Impulse = 1.25 (10 − 0)

= 12.5 N s

EXAMPLE 25 A car of mass 400 kg moving at a speed of 20 m/s is brought to rest in 20 s by a constant retarding force. Calculate (a) change in momentum and (b) the retarding force.

Solution: Given,

Mass of the car (m) = 400 kg

Initial speed (u) = 20 m/s

Final speed (v) = 0 (car comes to rest finally)

Time (t) = 20 s

To calculate : (i) Change in momentum (Δp) = ?

(ii) Retarding force (F) = ?

Formula to be used : (i) $\Delta p = m(v - u)$

(ii) Retarding force $(F) = m \times a$

$$= m\frac{(v - u)}{t}$$

(i) Calculations for

$$\Delta p = m(v - u)$$
$$= 400(0 - 20)$$
$$\Delta p = -8000 \text{ kg m/s}$$

Negative sign shows that the final momentum is less than the initial momentum.

(ii) Calculation for F

$$F = \frac{m(v - u)}{t}$$
$$= \frac{400(0 - 20)}{20}$$
$$= \frac{-8000}{20}$$

$F = -400$ N (Negative sign shows that the force is retarding)

or Retarding force = 400 N

NUMERICAL PROBLEMS (UNSOLVED)

1. How much force is needed to accelerate a trolley of mass 20 g through 1 m/s^2 ? (Ans. 2×10^{-2} N)
2. A force of 100 N acts on a mass of 25 kg for 5 s. What velocity does it generate ? (Ans. 20 m/s)
3. A bullet leaves a rifle with a velocity of 100 m/s and the rifle

(mass = 2.5 kg) recoils with a velocity of 1 m/s. Find the mass of the bullet. (Ans. 0.25 kg).

4. A certain force acting on a mass of 15 kg for 3 s, gives it a velocity of 2 m/s. Find the magnitude of the force. (Ans. 10 N).

5. A cricket ball of mass 0.15 kg is moving with a velocity of 1.2 m/s. Find the impulse on the ball and the average force applied by the player if he is able to stop the ball in 0.18 s.
(Ans. – 0.18 N s, – 1 N s)

6. A motor car of mass 2000 kg is moving with a certain velocity. It is brought to rest by the application of brakes, within a distance of 20 m when the average resistance being offered to it is 5000 N. What was the velocity of the motor car ?
(Ans. 10 m/s)

7. A body of mass 0.5 kg undergoes a change of velocity of 4 cm/s in 4 s. What is the force acting on it ? (Ans. 5×10^{-3} N)

8. A force of 8 N acting on an 8 kg mass for 4 s provides it some velocity. Calculate the velocity. (Ans. 4 m/s)

9. What would be the weight of a body of mass 50 kg on the surface of the moon, where g = 1.6 m/s^2 ? What would be its mass ?
(Ans. 80 N, 50 kg)

10. A boy jumps a distance of 2 m on the surface of the earth. What distance will he jump on the surface of the moon where g is 1/6th the of its value on the surface of the earth ? (Ans. 12 m)

11. Two bodies of mass 1 kg and 2 kg respectively moving in the directions opposite to each other with a speed 5 m/s collide. Calculate the total momentum of the system before collision.
(Ans. – 4 kg m/s)

12. A bullet of mass 15 g leaves the barrel of a gun with a velocity of 120 m/s. The gun recoils with a velocity of 1 m/s. The gun recoils with a velocity of 1 m/s. Find the mass of the gun.
(Ans. 1.8 kg)

13. A force of 3 N acts on a mass of 0.5 kg at rest for 10 s. Find the final velocity and the momentum of the body after 10 s.
(Ans. 60 m/s, 30 kg m/s)

14. A force of 80 N acting on a certain mass for 3.0 s gives it a velocity of 6.0 m/s. Find the mass of the body if the body was initially at rest. (Ans. 40 kg)

15. A toy of mass 0.1 kg acquires a speed of 5.0 m/s when pushed forward, what is the impulse given to the toy ?

(Ans. 5.0 N)

16. A projectile weighing 200 kg is fired from a gun with a velocity of 500 m/s. If the velocity of recoil of the gun is 12.5 m/s, calculate the mass of the gun. (Ans. 8000 kg)

17. A car of mass 2500 kg accelerates at the rate of 4.0 m/s^2 and then at the rate of 16 m/s^2. Calculate the ratio of the forces exerted by the engine in the two cases. (Ans. 1/4)

OBJECTIVE EVALUATION

1. Impulse is
   - (a) a scalar quantity
   - (b) a vector quantity
   - (c) neither a scalar nor a vector
   - (d) sometimes a scalar and sometimes a vector
2. Choose the wrong statement
   - (a) 1 kg–wt = 9.8 N
   - (b) Momentum is a vector quantity
   - (c) Force is always conserved
   - (d) Momentum is conserved in the absence of an external force
3. A long-jumper runs before jumping because
   - (a) he covers a greater distance
   - (b) he maintains momentum conservation
   - (c) he gains energy by running
   - (d) he gains momentum
4. If a rock is brought from the surface of the moon
   - (a) its mass will change
   - (b) its weight will change, but not mass
   - (c) both mass and weight will change
   - (d) its mass and weight will remain the same
5. If a kg–wt = 10 N, the value of gravitational intensity will be
   - (a) 10 m/s^2
   - (b) $\frac{1}{10}$ m/s^2
   - (c) 1 m/s^2
   - (d) $\frac{1}{100}$ m/s^2

6. The force acting on a mass of 1 g due to the gravitational pull on the earth is called 1 g–wt. One g–wt equals
   (a) 1 N (c) 980 dynes
   (b) 9.8 N (d) none of these

7. Two unequal masses (m_1 and m_2) are connected by a string which passes over a frictional pulley (Fig. 2.2). If m_1, m_2 and the table are frictionless, the acceleration of the masses would be
   (a) $\dfrac{m_1 g}{m_1 + m_2}$ (c) $\dfrac{m_1 + m_2}{m_1 g}$
   (b) $\dfrac{m_2 g}{m_1 + m_2}$ (d) none of these

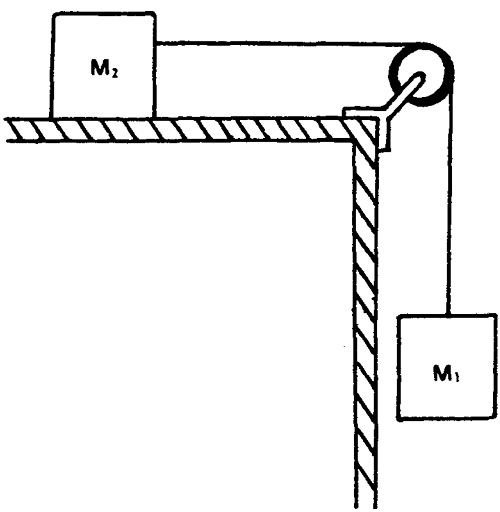


Fig. 2.2

8. The weight of a body would not be zero
   (a) at the centre of the earth
   (b) during a free fall
   (c) in interplanetary space
   (d) on a frictionless surface

9. An iron ball and a wooden ball of the same radius are released

from a height H in vacuum. The time taken by both of them to reach the ground are

(a) roughly equal
(b) unequal
(c) exactly equal
(d) in the inverse ratio of the their diameters

10. A man is standing on a boat in still water. If he walks towards the shore the boat will
(a) move away from the shore
(b) remain stationary
(c) move towards the shore
(d) sink

11. During a planned manoeuvre in a space flight, a free-floating astronaut A pushes another free-floating astronaut B, the mass of A being greater than that of B. Then, the magnitude of the force exerted by astronaut A on astronaut B is
(a) equal to zero
(b) equal to the force exerted by B on A
(c) greater than the force exerted by B on A
(d) less than the force exerted by B on A

12. In the above problem, during a push
(a) the acceleration of A is greater than that of B
(b) the acceleration of A is less than that of B
(c) neither is accelerated
(d) their accelerations are equal in magnitude but opposite in direction

13. A bullet of mass A and velocity B is fired into a block of wood of mass C. If loss of any mass and friction be neglected, the velocity of the system must be
(a) $\frac{AB}{A + C}$
(b) $\frac{A + C}{BC}$
(c) $\frac{AC}{B + C}$
(d) $\frac{A + B}{AC}$

14. A single horizontal force F is applied to a block of mass M, which is in contact with another block of mass M (Fig. 2.3). If the surfaces are frictionless the force between the blocks is
(a) $\frac{M_1F}{M_2}$
(b) $\frac{M_1M_2}{M_1 + M_2}$

(c) $\frac{M_2F}{M_1 + M_2}$ (d) none of these

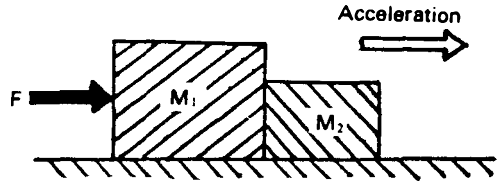


Fig. 2.3

15. A driver accelerates his car first at the rate of 1.8 m/s^2 and then at the rate of 1.2 m/s^2. The ratio of the forces exerted by the engines will be respectively equal to
(a) 2 : 3 (c) 2 : 1
(b) 1 : 2 (d) 3 : 2

16. A body of mass 5 kg undergoes a change in speed from 30 to 40 m/s. Its momentum would increase by
(a) 50 kg–m/s (c) 150 km–g/s
(b) 75 kg–m/s (d) 350 kg–m/s

17. The force needed to produce an acceleration of 6 m/s^2 in a ball of mass 4 kg will be
(a) 24 N (c) 32 N
(b) 30 N (d) 36 N

18. A body of mass 5 kg undergoes a change in speed from 20 to 0.20 m/s. The momentum of the body would
(a) increase by 99 kg m/s (c) increase by 101 kg m/s
(b) decrease by 99 kg m/s (d) decrease by 101 kg m/s

19. A bullet of mass 0.01 kg is fired from a gun weighing 5.0 kg. If the initial speed of the bullet is 250 m/s, calculate the speed with which the gun recoils.
(a) – 0.50 m/s (c) – 0.25 m/s
(b) + 0.05 m/s (d) + 0.25 m/s

20. A body of mass 100 g is moving with a velocity of 15 m/s. The momentum associated with the ball will be

(a) 1.5 kg m/s^2 (c) 2.5 kg m/s
(b) 1.5 kg m/s (d) 3.2 N s

21. A number of discs, each of momentum M kg–m/s, are striking a wall at the rate of n discs per minute. The force associated with these discs, in newtons, would be

(a) $\frac{Mn}{60}$ (c) $\frac{M}{60\,n}$

(b) $60\,Mn$ (d) $\frac{n}{60\,M}$

22. In the above problem, the force exerted by the wall on the discs would be (in newtons)

(a) $\frac{Mn}{60}$ (c) $\frac{M}{60\,n}$

(b) $60\,Mn$ (d) $\frac{n}{60\,M}$

23. If action and reaction were to act on the same body,
(a) the resultant would be zero
(b) the body would not move at all
(c) both (a) and (b) are correct
(d) neither (a) nor (b) is correct

24. A stationary ball weighing 0.25 kg acquires a speed of 10 m/s when hit by a hockey stick. The impulse imparted to the ball is
(a) 2.5 N s (c)1.5 N s
(b) 2.0 N s (d) 0.5 N s

25. A stone is tied to the middle of a string and suspended from one end as shown in Fig. 2.4. Here S is the stone and O is the point of suspension. If you give a sharp jerk at P, the string will break
(a) below the stone
(b) at the point P itself
(c) from above the stone
(d) nothing can be decided

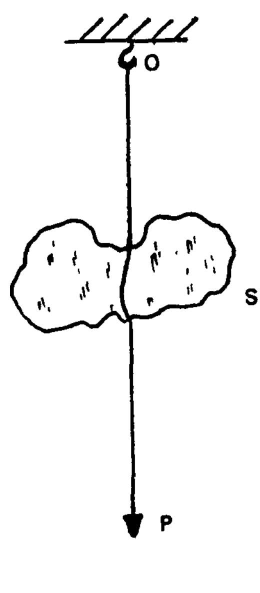


Fig. 2.4

26. In the above problem, if we

increase the pull at P gradually, the string will break

(a) below the stone (c) above the stone

(b) at the point P itself (d) nothing can be decided

27. The above problem can be explained on the basis of the property of

(a) inertia (c) momentum

(b) force (d) torque

28. The combined effect of mass and velocity is taken into account by a physical quantity called

(a) torque (c) momentum

(b) moment of force (d) moment of momentum

29. Momentum is a measure of

(a) weight (c) quantity of motion

(b) mass (d) velocity

30. Momentum has the same units as that of

(a) impulse (c) moment of momentum

(b) torque (d) couple

31. Consider two spring balances hooked as shown in Fig. 2.5. We pull them in opposite directions. If the reading shown by A is 1.5 N, the reading shown by B will be

(a) 1.5 N (c) 3.0 N

(b) 2.5 N (d) zero

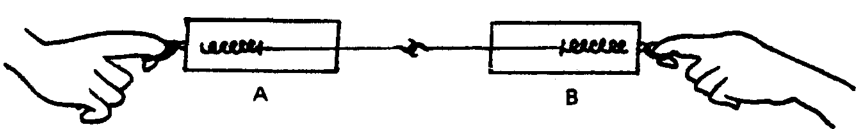


Fig. 2.5

32. A hammer weighing 3 kg, moving with a velocity of 10 m/s, strikes against the head of a spike and drives it into a block of wood. If the hammer comes to rest in 0.025 s, the impulse associated with the ball will be

(a) 30 N s
(b) – 30 N s
(c) 15 N s
(d) – 15 N s

33. In the above problem, the average retarding force acting on the spike will be
(a) 600 N
(b) – 600 N
(c) 1200 N
(d) – 1200 N

34. In a tug-of-war between the teams A and B, the rope breaks at a point which is nearer to A. Then
(a) A has applied more force
(b) B has applied more force
(c) A and B both have applied same force
(d) none has applied any force

35. A rocket works on the
(a) first law of motion
(b) second law of motion
(c) third law of motion
(d) law of conservation of energy

36. A metallic ball strikes a wall and falls down whereas a tennis ball having the same mass and velocity bounces back. The reason for this is that
(a) both suffer equal change in momentum
(b) the tennis ball suffers a greater change in momentum
(c) metallic ball suffers a greater change in momentum
(d) the momentum of the tennis ball is less than that of the metallic ball.

37. When a bicycle travels on a rough surface, its speed
(a) increases
(b) decreases
(c) remains the same
(d) none of these

38. If you are asked to push an object so that the acceleration produced in it is now twice as before, then the force required will be
(a) twice as before
(b) half as before
(c) same as before
(d) four times as before

39. It is difficult to walk on ice because of
(a) absence of friction
(b) absence of inertia
(c) more inertia
(d) more friction

40. The law which defines force is
(a) Newton's third law of motion

(b) Newton's first law of motion
(c) Newton's second law of motion
(d) Newton's law of gravitation

41. The law which gives a quantitative measurement of force is
(a) Newton's third law of motion
(b) Newton's first law of motion
(c) Newton's second law of motion
(d) Newton's law of gravitation

42. Internal forces
(a) are always balanced forces
(b) never balanced forces
(c) may or may not be balanced
(d) none of these

43. External forces
(a) are always balanced
(b) never balanced
(c) may or may not be balanced
(d) none of these

44. Friction between any two objects is due to
(a) attraction between them
(b) repulsion between them
(c) some adhesive forces between them
(d) irregularities on the surfaces

45. A and B are two objects with mass 6 kg and 34 kg respectively
(a) A has more inertia than B
(b) B has more inertia than A
(c) A and B both have same inertia
(d) none of the above is true

True or False Statements

1. Force may or may not produce any motion in a body
2. Action and reaction act on the same body
3. $1 \text{ N} = 1 \text{ kg} \times 1 \text{ m/s}^2$
4. The SI unit for impulse is kg m/s
5. Impulse represents the rate of change of momentum of a body

6. Momentum is a vector quantity
7. 1 N is that force which produces an acceleration of 1 m/s^2 in a body of mass 1 g.
8. In the game of carrom, we use powder to decrease friction
9. In any interaction there are always at least two forces in play
10. The force of friction is smaller in solids than in liquids
11. The first law of motion is also known as Galileo's law of inertia.
12. A ball thrown upwards in a running train continues to move along the train due to inertia of motion.
13. Balanced forces do not change the speed of the body.
14. Impulse is a scalar quantity.
15. If the resultant of forces is zero, they are said to balanced.

ANSWERS (OBJECTIVE EVALUATIONS)

1. (b)	2. (c)	3. (d)	4. (b)	5. (a)	6. (c)	7. (a)	8.(d)	9.(c)
10. (a)	11. (b)	12. (b)	13. (a)	14. (c)	15. (d)	16. (a)	17. (a)	18. (b)
19. (b)	20. (b)	21. (a)	22. (a)	23. (c)	24. (a)	25. (a)	26. (c)	27. (a)
28. (c)	29. (c)	30 (a)	31. (a)	32. (b)	33. (d)	34. (a)	35. (c)	36. (b)
37. (b)	38. (a)	39. (a)	40. (b)	41. (c)	42. (a)	43. (a)	44. (d)	45. (b)

ANSWERS (TRUE OF FALSE)

1. T	2. F	3. T	4. F	5. F	6. T	7. F	8. T	9. T
10. F	11. T	12. T	13. T	14. F	15. T			

UNIT THREE
GRAVITATION

REVIEW CONCEPTS

Gravitational force is that force which attracts all bodies (objects) towards its centre.

Law of gravitation : Every body in this universe attracts every other body with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres.

Acceleration due to gravity is the acceleration produced in a body due to gravity. It is independent of the mass of a body.

The value of g = 9.8 m/s^2. It varies from place to place.

Mass is the amount of quantity of matter possessed by a body. It is measured by a beam balance.
SI units — kg.

Weight of a body is the force with which it is pulled towards the centre of the earth. It is measured by a spring balance.
SI units : newton (N).

Weightlessness is that stage when weight becomes zero. A freely falling body is also weightless.

Projectile is an object which is thrown up or down.

Coulomb's law of electric force states that the force of attrac tion or repulsion between two charged bodies is directly proportiona to the product of charges and inversely proportional to the square the distance between them.

Formulae

1. $F = m \times g$ or $m = \dfrac{F}{g}$

   where F = force or weight
   m = mass and
   g = acceleration due to gravity

2. $v = u + at$ or $v = u + gt$

   $\Rightarrow v - u = at$ or $v - u = gt$

where v = final velocity
u = initial velocity
a = acceleration
g = acceleration due to gravity and
t = time

3. $S = ut + \frac{1}{2}at^2$ or $S = ut + \frac{1}{2}gt^2$

where S = distance (other symbols have the same meaning as written above)

4. $v^2 - u^2 = 2aS$ or $v^2 = u^2 + 2aS$

5. $F = G\dfrac{m_1 \times m_2}{r^2}$

where F = force
m_1, m_2 = mass of two bodies
r = distance between the centre of two bodies
G = gravitational constant

6. $g = G\dfrac{M}{r^2}$

where g = acceleration due to gravity
G = Gravitational constant
M = mass
r = distance

NUMERICAL PROBLEMS (SOLVED)

EXAMPLE 1 What is the mass of an object whose weight is 49 N? (Given g = 9. 8 m/s^2)

Solution: Given,

Weight (w) = 49 N

Acceleration due to gravity (g) = 9.8 m/s^2

To calculate : Mass of the body (m) = ?

Formula to be used : $F = mg = m = \dfrac{F}{g}$

substituting the given value of F and g,

we get $$m = \frac{49}{9.8} = 5.0 \text{ kg}$$

EXAMPLE 2 How much would a 70 kg man weight on the moon ? What would be his mass on earth and on the moon ?
(Given : acceleration due to gravity on moon = 1.63 m/s^2)

Solution: Given,
Mass (m) = 70kg
Acceleration due to gravity (g) = 1.63 m/s^2

To calculate : (i) weight on the moon (F) = ?
(ii) Mass on the earth (m) = ?
(iii) Mass on the moon (m) = ?

Formula to be used : (i) $F = m \times g$

substituting the given value of m and g

we get, $$F = 70 \times 1.63 = 144.10 \text{ N}$$
(ii) 70 kg
(iii) 70 kg (since mass is the quantity of matter possessed by a body it remains constant).

EXAMPLE 3 A stone is dropped from the edge of a roof.
(i) how long does it take to fall 4.9 m ?
(ii) how fast does it move at the end of that fall ?
(iii) how fast does it move at the end of 7.9 m ?
(iv) what is the acceleration after 1 s and after 2 s ?

Solution: Given,
(i) distance (S) = 4.9 m
Acceleration due to gravity (g) = 9.8 m/s^2
Initial velocity (u) = 0
(ii) distance (S) = 7.9 m
(iii) time (t) = 1 s and 2 s

To calculate : (i) time (t) = ?
(ii) final velocity (v) = ?
(iii) acceleration (a) = ?

Formula to be used: (i) $S = ut + \frac{1}{2}gt^2$
(ii) $v = u + gt$

$$\text{(iii) } v^2 - u^2 = 2gS$$

(i) To find t, put the value of S, u and g in equation (i), we get,

$$4.9 = (0 \times t) + \frac{1}{2} \times 9.8 \times t^2$$

$$4.9 = 0 + 4.9t^2$$

$$t^2 = 1 \quad \text{or} \quad t = 1 \text{ s}$$

(ii) To find v using equation (ii), putting the value of t and g we get,

$$v = 0 + (9.8 \times 1)$$

$$= 9.8 \text{ m/s}^2$$

(iii) To find v using equation (iii), substituting the value of u, g and S, we get,

$$v^2 - (0)^2 = 2 \times 9.8 \times 7.9$$

$$v^2 = 154.84$$

$$v = 12.44 \text{ m/s}$$

(iv) Same (since acceleration of a body falling freely under gravity is same).

EXAMPLE 4 If you weigh 60 kg on earth, how far must you go from the centre of the earth so that you weigh 30 kg ?

Solution: Given,

Weight on the earth (mg) = 60 kg.

Radius of the earth (r) = 6400×10 m

To calculate : Distance from the centre of the earth (r) = ?

Formula to be used : Weight = $m \times g$

Since we know that mass is a constant quantity and only acceleration due to gravity changes from place to place, so we have to find out new acceleration due to gravity (g') so that (mg') = 30 kg.

Given, $mg = 60$ kg and $mg' = 30$ kg.

Dividing (i) by (ii), i.e.

$$\frac{mg}{mg'} = \frac{60}{30}$$

$$\frac{g}{g'} = 2$$

But $$g = \frac{Gm}{r^2}$$

$$\therefore \qquad g' = \frac{Gm}{(r')^2}$$

$$\therefore \qquad \frac{g}{g'} = \frac{Gm}{r^2} \Big/ \frac{Gm}{(r')^2}$$

$$\Rightarrow \qquad \frac{g}{g'} = \frac{(r')^2}{r^2} = 2$$

$$\frac{(r')^2}{r^2} = 2 \quad \text{or} \quad (r')^2 = 2 \times r^2$$

$$r' = \sqrt{2} \times 6400 \times 10$$

$$r' = \sqrt{2} \times 6400 \text{ km}$$

$$= 9049.6 \text{ km}$$

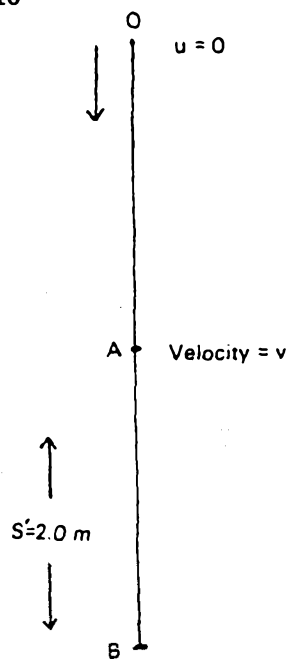


Fig 3.1

EXAMPLE 5 A stone drops from the edge of the roof. It passes a window 2 m high in 0.1 s. How far is the roof above the top of window?

Solution: Given,

Distance covered in passing the window $(S') = 2.0$ m

Acceleration due to gravity $(g) = 9.8$ m/s^2

Time $(t) = 0.1$ s

Let the velocity at A $(u) = v$

To calculate : Distance (OA) = $S = ?$

Formula to be used:

(i) $S = ut + \frac{1}{2}gt^2$

(ii) $v^2 - u^2 = 2gS$

To find (v) substituting the value of u, g and S in equation (i), we get

$$2 = (v \times 0.1) + \frac{1}{2} \times 9.8 \times (0.1)^2$$

$$2 = v \times 0.1 + 0.049$$

=> $$v = 1.951 \times 10$$

$$v = 19.51 \text{ m/s}$$

To find (S), put the value of v and g ('u' in this case is zero)

$$\therefore \quad (19.51)^2 - (0)^2 = 2 \times 9.8 \times S$$

=> $$S = \frac{19.51 \times 19.51}{2 \times 9.8}$$

$$S = 19.42 \text{ m}$$

EXAMPLE 6 A boy on a roof 49 m high drops a stone. One second later he throws a second stone after the first. They both hit the ground at the same time. With what speed did he throw the second stone?

Solution: Given,

Distance (S) = 49 m

Initial velocity (u) for first stone = 0

Acceleration due to gravity (g) = 9.8 m/s^2

To calculate : Initial speed (u) for the 2nd stone = ?

Formula to be used : $S = ut + \frac{1}{2}gt^2$

substituting the value of S, u and g to calculate t

$$49 = (0 \times t) + \left(\frac{1}{2} \times 9.8\right)(t^2)$$

$$49 = 4.9 \times t^2$$

$$t^2 = 10$$

$$t = 3.162 \text{ s}$$

Time taken by second stone to cover the same vertical distance (49 m)

$$= 3.162 - 1.0 = 2.162 \text{ s}$$

(since second stone was thrown 1 s after the first stone)

Let u be the initial velocity of the second stone (to be calculated).

Using $$S = ut + \frac{1}{2}gt^2$$

$$49 = u \times (2.162) + \frac{1}{2}(9.8)(2.162)^2$$

$$\frac{49 - 1/2\,(9.8)\,(2.162)^2}{2.162} = u$$

$$u = 12.07 \text{ m/s}$$

EXAMPLE 7 A body has a weight of 10 kg on the surface of earth. What will be its weight when taken to the entre of the earth?

Solution: Given,

Mass of the body (m) = 10 kg

Acceleration due to gravity (g) = 0

(Since g = 0 at the centre of the earth)

To calculate : Weight (F) = ?

Formula to be used : $F = m \times g$

$\therefore$ $F = 10 \times 0 = 0$ N

EXAMPLE 8 Find the force exerted by the earth on a stone weighing 1 kg. Weight of the earth is 6×10^{24} kg, radius of the earth is 6.5×10^{6} m.

Solution: Given,

Mass of the stone (m) = 1kg

Mass of the earth (M_e) = 6×10^{24} kg

Distance (r) = 6.5×10^{6} m

Gravitational constant (G) = 6.6734×10^{-11} Nm²/kg

To calculate : Force (F) = ?

Formula to be used : $F = G\dfrac{M_e \times m}{r^2}$

Substituting the given values

$$F = \underset{\times 10^{-11}}{6.6734} \times \frac{(6 \times 10^{24})(1)}{(6.5 \times 10^{6})^{2}}$$

$$= \frac{6.6734 \times 10^{-11} \times 6 \times 10^{24}}{6.5 \times 6.5 \times 10^{12}}$$

$$= \frac{6.6734 \times 6 \times 10^{24-12-11}}{6.5 \times 6.5}$$

$$F = 9.8 \text{ N}$$

EXAMPLE 9 A ball is thrown up with a speed of 0.5 m/s. How high will it go before it begins to fall?

Solution: Given,

Initial speed (u) = 0.5 m/s

Acceleration due to gravity (g) = − 9.8 m/s^2

(g' is taken to be negative since the body is going against the gravity)

Final velocity (v) = 0 (since the body stops finally)

To calculate : Distance (S) = ?

Formula to be used : $v^2 - u^2 = 2gs$

substituting the given values,

$$(0)^2 - (0.5)^2 = 2(-9.8)\ (S)$$

$$-(0.5 \times 0.5) = -2 \times 9.8 \times S$$

$$\Rightarrow \qquad S = \frac{0.5 \times 0.5}{2 \times 9.8}$$

$$S = 0.012 \text{ m}$$

EXAMPLE 10 A body of mass 120 kg is taken to the surface of the moon, where acceleration due to gravity is 1/6th of that on the surface of the earth. What will be the weight of the body on the surface of the moon?

Solution: Given,

Mass of the body (m) = 120 kg

Acceleration due to gravity (g') = $\frac{9.8}{6}$ = 1.63 m/s^2

To calculate : Weight (w) = ?

Formula to be used : $w = m \times g'$

where g' is the acceleration due to gravity on the surface of the moon.

$$w = 120 \times 1.63$$

$$w = 196.0 \text{ N}$$

EXAMPLE 11 Calculate the force exerted by the earth on the moon. Given mass of earth M_e = 6 × 10^{24} kg, mass of the moon m = 7.4 × 10^{22} kg and the distance of the moon from the earth = 3.84 × 10^5 km.

Solution: Given,

Mass of the earth (M_e) = 6 × 10^{24} kg

Mass of the moon (m) = 7.4 × 10^{22} km

Distance $(r) = 3.84 \times 10^5$ km

$= 3.84 \times 10^8$ m

Gravitational constant $(G) = 6.7 \times 10^{-11}$ Nm^2/kg^2

To calculate : Force (F) = ?

Formula to be used : $F = G\dfrac{M_e \times m}{r^2}$

Substituting the given values,

$$F = 6.7 \times 10^{-11}\frac{(6 \times 10^{24})\ (7.4 \times 10^{22})}{(3.84 \times 10^8)^2}$$

$$= \frac{6.7 \times 6 \times 7.4}{3.84 \times 3.84} \times 10^{19}$$

$$F = 2.01 \times 10^{20}\ N$$

EXAMPLE 12 If the force of attraction between the earth and a body of mass (m) is 9×10^7 N. What would be the value of m ? Given $G = 7.6 \times 10^{-11}$ Nm^2/kg^2, radius of the earth $r = 6.4 \times 10^6$ m, $M_e = 6.4 \times 10^{24}$ kg.

Solution: Given,

Force of attraction $(F) = 9 \times 10^7$ N

Mass of earth $(M_e) = 6.0 \times 10^{24}$ kg

Gravitational constant $(G) = 6.7 \times 10^{-11}$ Nm^2/kg^2

Radius of the earth $(r) = 6.4 \times 10^6$ m

To calculate : Mass of the body (m) = ?

Formula to be used : $F = G\dfrac{M_e \times m}{r^2}$

=> $m = \dfrac{F \times r^2}{G \times M_e}$

Substituting the given values,

$$m = \frac{(9 \times 10^7)\ (6.4 \times 10^6)^2}{6.7 \times 10^{-11} \times 6.0 \times 10^{24}}$$

$$= \frac{(9 \times 10^7)\ (6.4 \times 6.4 \times 10^{12})}{6.7 \times 10^{-11} \times 6 \times 10^{24}}$$

$$= \frac{9 \times 6.4 \times 6.4}{6.7 \times 6} \times 10^6$$

$$m = 9.17 \times 10^6 \text{ kg}$$

EXAMPLE 13 What is the force between two spheres having mass 20 kg each separated by a distance of 50 cm ?

Solution: Given,

Mass $(m_1, m_2) = 20$ kg

Distance $(r) = 50$ cm $= 0.50$ m

Gravitational constant $(G) = 6.7 \times 10^{-11}$ Nm^2/kg^2

To calculate : Force $(F) = ?$

Formula to be used : $F = G \dfrac{m_1 \times m_2}{r^2}$

Substituting the given values,

$$F = 6.7 \times 10^{-11} \frac{(20) \times (20)}{(0.50)^2}$$

$$F = 1.07 \times 10^{-7} \text{ N}$$

EXAMPLE 14 A body weighing 50 kg is standing on the floor of a lift. Find the weight when the

(i) lift moves up with uniform velocity

(ii) lift moves down with an acceleration of 4.9 m/s^2

(iii) lift moves up with an acceleration of 4.9 m/s^2

(iv) lift begins to fall freely under gravity.

Solution: Given,

Mass of the body $(m) = 50$ kg

Acceleration due to gravity $(g) = 9.8$ m/s^2

To calculate : Weight $(w) = ?$

Formula to be used : $w = m(g \pm a)$

(i) uniform velocity means acceleration on the lift is zero, i.e. $a = 0$

$$w = m(g \pm 0) = mg$$

$$w = 50 \times 9.8 = 490 \text{ N}$$

i.e., the weight will be same as in stationary

(ii) $a = -4.9$ m/s^2

$$w = m(g-a) = 50\,(9.8 - 4.9)$$
$$= 50 \times 4.9$$
=> $$w = 245 \text{ N}$$

(iii) $$a = 4.9 \text{ m/s}^2$$
$$w = m\,(g + a)$$
$$= 50\,(9.8 + 4.9)$$
$$= 50 \times 14.7 = 735 \text{ N}$$

(iv) $$a = -g$$
$$w = m\,(g - g)$$
$$w = 0$$ i.e., weightlessness.

EXAMPLE 15 A stone is dropped from a tower with no initial velocity. It is observed that it strikes the ground after 5 s. Find the velocity of impact and the height of the tower.

Solution: Given,

Time (t) = 5 s

Initial velocity (u) = 0

Acceleration due to gravity (g) = 9.8 m/s^2

To calculate : (i) Velocity (v) = ?

(ii) Height of the tower (S) = ?

Formula to be used : (i) $v = u + at$

(ii) $S = ut + \frac{1}{2} gt^2$

(i) To find v $\quad v = u + gt$

Substituting the value of u, g, t in the equation,

$$v = 0 + (9.8)\,(5)$$
$$v = 49.0 \text{ m/s}$$

(ii) To find S $\quad S = ut + \frac{1}{2} gt^2$

Substituting the value of u, t and g in this equation,

$$S = (0 \times 5) + \frac{1}{2} \times (9.8)\,(5)^2$$
$$= 0 + \frac{1}{2} \times 9.8 \times 25$$
$$= 122.5 \text{ m}$$

NUMERICAL PROBLEMS (UNSOLVED)

1. The value of the force of gravity on a boy of mass 40 kg was found to be 2400 N. Using $M_e = 6 \times 10^{24}$ kg and $r = 6.4 \times 10^6$ m, find the value of G. (Ans. 6.67×10^{-11} Nm²/kg²)

2. Compute the force of gravity on a body of mass 80 kg lying on the surface of the earth. Given mass of the earth 6×10^{24} kg, radius of the earth 6.4×10^6 m and $G = 6.67 \times 10^{-11}$ Nm²/kg². (Ans. $g = 9.77$ m/s², 781.6 N)

3. Calculate the value of acceleration due to gravity on the surface of the moon (mass of moon = 7.4×10^{22} kg, radius of moon = 1740 km, $G = 6.673 \times 10^{-11}$ Nm²/kg²) (Ans. 1.63 m/s²)

4. Calculate the mass of earth. Given $g = 9.8$ m/s², $r = 6370$ km and $G = 6.67 \times 10^{-11}$ Nm²/kg². (Ans. 5.96×10^{24} kg)

5. If $g_{moon}/g_{earth} = 1/6$, what height will a man of 60 kg jump safely on the moon, if he jumps 1.5 m on the earth. (Ans. 9 m)

6. A force 20 N acts on a body whose mass is 9.8 kg. What is its acceleration ? (Ans. 2.04 m/s)

7. A force of 2 kg wt acts on a body of mass 4.9 kg. Calculate the acceleration. (g = 9.8 m/s) (Ans. 4.0 m/s²)

8. A ball dropped from a balloon at rest clears a tower 81 m high during the last quarter second of its journey. Find the height of the balloon and the velocity of the body when it reaches the ground. (Ans. 2684.2 m, 324.38 m/s)

9. A ball is dropped from a height of 1 m. How long does it take for the ball to reach the ground ? With what speed does it hit the ground ? (Ans. 0.45 s, 4.4 m/s)

10. Calculate the vertical distance through which the moon falls in 2 days. (Ans. 40642 km)

11. The earth's gravitational force causes an acceleration of 5.5 m/s² in a 2 kg mass somewhere in space. How much would the acceleration of a 3 kg mass be at the same place ? (Ans. same)

OBJECTIVE EVALUATION

1. The universal law of gravitation was postulated by
   (a) Copernicus (b) Newton

(c) Galileo (d) Archimedes

2. A rock is brought from the surface of the moon,
   (a) its mass will change
   (b) its weight will change but not mass
   (c) both mass and weight will change
   (d) its mass and weight both will remain same.
3. A body is weighed at the poles and then at the equator. The weight
   (a) at the equator will be greater than at the poles
   (b) at the poles will be greater than at the equator
   (c) at the poles will be equal to the weight at the equator
   (d) depends upon the object
4. A lead ball and a snow ball of identical radius are released from a certain height in vacuum. The time taken by both of them to reach the ground are
   (a) exactly equal (c) unequal
   (b) roughly equal (d) in the ratio of the density of lead and snow
5. The weight of a body at the centre of the earth is
   (a) zero (c) maximum
   (b) equal to its mass (d) infinite
6. The SI unit of g is
   (a) m^2/s (b) m/s^2 (c) s/m^2 (d) m/s
7. The SI unit of G is
   (a) $N^2 - m^2/kg$ (c) $N - m/kg$
   (b) $N - m^2/kg$ (d) $N - m^2/kg^2$
8. Choose the correct statement
   (a) all bodies repel each other in this universe
   (b) our earth does not behave like a magnet
   (c) acceleration due to gravity is 9.8 m/s
   (d) all bodies fall at the same rate in vacuum.
9. The maximum weight of a body is
   (a) at the centre of the earth
   (b) inside the earth
   (c) on the surface of the earth
   (d) above the surface of the earth

10. If the distance between two masses be doubled then the force between them will be

    (a) 1/4 times (b) 4 times (c) 1/2 times (d) 2 times

11. A body falls freely towards the earth with

    (a) uniform speed
    (b) uniform velocity
    (c) uniform acceleration
    (d) none of these

12. If the mass of a body is M on the surface of the earth, then its mass on the surface of the moon will be

    (a) $\frac{M}{6}$
    (b) M
    (c) $M + 6$
    (d) $M \times 6$

13. If a person jumps 1 m at the surface of the earth, he will jump 6 metres at the surface of the moon. Therefore the ratio of moon's acceleration due to gravity with respect to earth's acceleration due to gravity would be

    (a) 6 (b) 1/6 (c) 0.6 (d) 0.06

14. Choose the correct statement

    (a) weight is a vector quantity
    (b) the weight of a body in interplanetary space is maximum
    (c) weight increases when the bodies go up
    (d) 1 N = 1 kg × 1 m/s

15. The value of acceleration due to gravity near the earth's surface is

    (a) 8.9 m/s^2
    (b) 8.9 m/s
    (c) 9.8 m/s^2
    (d) 9.8 m/s

16. The force of gravitation between two bodies does not depend upon

    (a) their separation
    (b) the gravitational constant
    (c) the product of their masses
    (d) the sum of their masses

17. The type of force which exists between charged bodies is

    (a) only gravitational
    (b) only electrical
    (c) neither gravitational nor electrical

(d) both electrical and gravitational

18. When a fruit falls from a tree
    (a) only the earth attracts the fruit
    (b) both the earth and the fruit attracts each other
    (c) only fruit attracts the earth
    (d) they repel each other
19. When an object is thrown up, the force of gravity,
    (a) acts in the direction of the motion
    (b) acts in the opposite direction of the motion
    (c) decreases as the body moves up
    (d) increases as the body moves up
20. Newton's law of gravitation
    (a) can be verified in the laboratory
    (b) is valid only in the solar system
    (c) cannot be verified but is true
    (d) is valid only on earth

True or False Statements

1. Acceleration due to gravity depends upon the mass of body.
2. Mass is measured by spring balance.
3. Projectile is a body which moves in space without any fuel or propulsion.
4. G and g are same.
5. Weight of a body $w = m \times g$.
6. Bodies falling freely under gravity have no weight.
7. The value of G depends upon the mass of two objects.
8. If a spring balance, holding a heavy object is released it will read zero weight.
9. The value of G is high if the radius of the body is more and less if radius is less.
10. The gravitational force between two bodies changes if a material body is placed between them.
11. The acceleration of a body thrown up is numerically the same

as the acceleration of a downward falling body but opposite in sign.

12. The value of g is zero at the centre of the earth.
13. All objects attract each other along the line joining their centre of mass.
14. The atmosphere is not separated from the surface of the earth due to Coulombian force of attraction.
15. Acceleration due to gravity $g = G\dfrac{M}{R^2}$

ANSWERS (OBJECTIVE EVALUATION)

1. (b)	2. (b)	3. (a)	4. (a)	5. (a)	6. (b)	7. (d)	8. (d)	9. (c)
10. (a)	11. (c)	12. (b)	13. (b)	14. (a)	15. (c)	16. (d)	17. (d)	18. (b)
19. (b)	20. (a)							

ANSWERS (TRUE / FALSE)

1. F	2. F	3. T	4. F	5. T	6. T	7. F	8. T	9. F
10. T	11. T	12. T	13. T	14. F	15. T			

UNIT FOUR
SIMPLE PENDULUM AND RESTORING FORCE

REVIEW CONCEPTS

A simple pendulum is a body suspended to a high inextensible, fixed thread.

Length of the pendulum is the distance between the rigid support (the point of suspension) up to the centre of the bob. It is denoted by l.

An oscillation is the motion of the mass from one extreme position to the other and then back.

Time period (T) is the time taken by the body to complete one oscillation.

(a) Time period depends upon the length of the pendulum as $T \propto \sqrt{l}$.

(b) Time period depends upon the acceleration due to gravity as $T \propto \sqrt{(1/g)}$.

(c) Time period is independent of the mass of the body.

(d) Time period is independent of the material of the body.

Amplitude of an oscillation is the maximum displacement through which the body is displaced.

Restoring force is that which tends to bring the body back to its original position or the mean position.

Origin of the restoring force : It arises due to the pull of the gravitational force and the pull of the string.

(a) At mean position, the two forces are balanced

(b) At extreme positions, the pull of the string is less than the gravitational force.

Formulae

1. Time period $T = 2\pi \sqrt{\dfrac{l}{g}}$

   where $T =$ time period

l = length of the pendulum and
g = acceleration due to gravity

2. Length of the pendulum $l = \dfrac{T^2 \times g}{4\pi^2}$

where l = length of the pendulum
T = time period and
g = acceleration due to gravity

3. Acceleration due to gravity $g = 4\pi^2 \times \dfrac{l}{T^2}$

where g = acceleration due to gravity
l = length of the pendulum and
T = time period

NUMERICAL PROBLEMS (SOLVED)

EXAMPLE 1 What is the period of a pendulum of length 9.8 m? (g = 9.8 m/s^2)

Solution: Given,

Length (l) = 9.8 m

Acceleration due to gravity (g) = 9.8 m/s^2

To calculate : Time period (T) = ?

Formula to be used : $T = 2\pi\sqrt{\dfrac{l}{g}}$

Substituting the given values, we get,

$$T = 2\pi\sqrt{\frac{9.8}{9.8}}$$

$$T = 2\pi$$

$$= 2 \times 3.14 = 6.28 \text{ s}$$

EXAMPLE 2 What is the length of the pendulum whose period is 1 second ? (g = 9.8 m/s^2)

Solution: Given,

Time period (T) = 1 s

Acceleration due to gravity (g) = 9.8 m/s^2

To calculate : Length (l) = ?

Formula to be used : $l = \dfrac{T^2 \times g}{4\pi^2}$

Substituting the given values,

=> $l = \dfrac{(1)^2 \times 9.8}{4 \times 3.14 \times 3.14}$

$l = 0.22$ m

EXAMPLE 3 Find the time period of a pendulum whose length is 2 m.

Solution: Given,

Length (l) = 2 m

Acceleration due to gravity (g) = 9.8 m/s^2

To calculate : Time period (T) = ?

Formula to be used : $T = 2\pi\sqrt{\dfrac{l}{g}}$

$$T = 2\pi\sqrt{\frac{2}{9.8}}$$

$$T^2 = 4\pi^2 \times \frac{2}{9.8}$$

$$T^2 = \frac{4 \times 3.14 \times 3.14 \times 2}{9.8}$$

$$T^2 = 8.06$$

$\therefore$ $T = 2.83$ s

EXAMPLE 4 If the length of a pendulum becomes twice the original length what would be the new time period ?

Solution: Given,

Let the original length = l

and Original time period = T

New length = 2 l

To calculate : New time period (T) = ?

Formula to be used : $T = 2\pi\sqrt{\dfrac{l}{g}}$ (i)

For the new pendulum, replace T by T' and l by $2l$.

$$T' = 2\pi\sqrt{\frac{2l}{g}} \qquad \text{(ii)}$$

Compare (i) and (ii)

$$\frac{T'}{T} = \sqrt{\frac{2l}{l}}$$

=> $$\frac{T'}{T} = \sqrt{2}$$

$$= \left(\frac{T'}{T}\right)^2 = 2$$

or $$(T')^2 = 2T^2$$

EXAMPLE 5 Find the value of g at a place where l/T^2 is found to be $0.248\ m/s^2$.

Solution: Given,

$$l \div T^2 = 0.248\ m/s^2$$

To calculate : Acceleration due to gravity (g) = ?

Formula to be used : $g = 4\pi^2 \times \frac{l}{T^2}$

Substituting the given value of l/T^2, we get

$$g = 4 \times 3.14 \times 3.14 \times 0.248$$

$$g = 9.8\ m/s^2$$

EXAMPLE 6 Find the length of the pendulum whose time period is 2 s (Given $g = 9.8\ m/s^2$)

Solution: Given,

Time period (T) = 2 s

Acceleration due to gravity (g) = $9.8\ m/s^2$

To calculate : Length (l) = ?

Formula to be used : $l = \frac{T^2 \times g}{4\pi^2}$

Substituting the given values, we get

$$l = \frac{(2)^2 \times 9.8 \times 7 \times 7}{4 \times 22 \times 22}$$

$$l = 0.99\ m \quad \text{or} \quad l \approx 1.0\ m$$

EXAMPLE 7 If a simple pendulum is taken to a place where acceleration due to gravity is half of the original, how will the time period of the pendulum vary ?

Solution: Given,

Acceleration due to gravity (g) $= g$

New acceleration due to gravity (g) $= g/2$

Original time period (T) $= T$

To calculate : New time period (T') $= ?$

Formula to be used : $T = 2\pi\sqrt{\dfrac{l}{g}}$ (i)

Write equation (i) for new time period

$$T' = 2\pi\sqrt{\frac{l}{g/2}} \quad \text{or} \quad T' = 2\pi\sqrt{\frac{2l}{g}} \qquad \text{(ii)}$$

Compare (i) and (ii)

$$\frac{T'}{T} = \sqrt{2}$$

$$\left(\frac{T'}{T}\right)^2 = 2$$

$$(T')^2 = 2T^2.$$

NUMERICAL PROBLEMS (UNSOLVED)

1. Compute the length of the second's pendulum when the value of $g = 9.8$ m/s^2. ($T = 2.0$ sec.) (Ans. = 99. 3 cm)
2. The mass of the bob of a simple pendulum is 100 gm. The pendulum is at its equilibrium position. Find the restoring force. (Ans. 0.98 N)
3. A simple pendulum is kept in a lift which is accelerating upwards. What will happen to its time period? (Ans. Decreases)
4. A simple pendulum is kept in a lift which is moving upwards with a unifom speed. What will happen to its time period ? (Ans. No change)
5. A simple pendulum is kept in a lift which falls freely. What will be its time period ? (Ans. Infinite)
6. A brass sphere filled with mercury acts as the bob of a simple pendulum. The sphere has a hole at its bottom through which mercury is constantly oozing out. How will its time period vary with time ? (Ans. First increases then decreases and is ultimately equal to original time period)

7. What is the acceleration due to gravity at a place where its time period is 2π seconds and length is 1 m ? (Ans. 1 m/s^2)

OBJECTIVE EVALUATION

1. The period of pendulum depends upon

   (a) mass (b) length (c) amplitude (d) energy

2. A pendulum suspended from the ceiling of a train has a time period T when the train is at rest. When the train is accelerating with a uniform acceleration the time period will

   (a) increase (b) decrease

   (c) become infinite (d) remain unaffected

3. The time period T is found to depend upon L as

   (a) $T \propto L$ (b) $T \propto L^2$ (c) $T^2 \propto L$ (d) $T \propto \sqrt{\frac{1}{L}}$

4. The relation between T and g is given by

   (a) $T \propto g$ (b) $T \propto g^2$ (c) $T^2 \propto g$ (d) $T \propto \sqrt{\frac{1}{g}}$

5. The graph between L and T^2 is

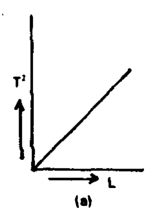
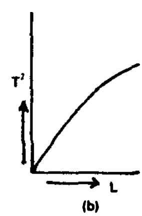


Fig. 4.1 (a)



(b)

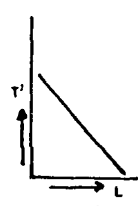
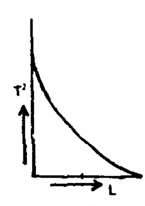


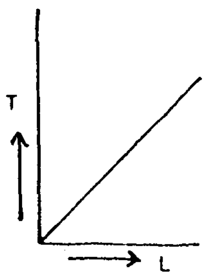
Fig. 4.1 (c)



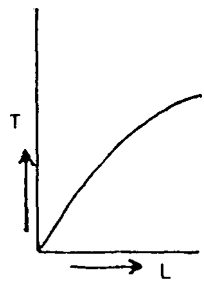
(d)

6. The oscillations of a pendulum slow down due to
   (a) the force exerted by air and friction at the support
   (b) the before exerted by air only
   (c) the forces exerted by friction at the support only
   (d) none of these
7. If a pendulum is allowed to oscillate into a jar containing water, its time period will
   (a) increase (b) decrease
   (c) remain same (d) none of these
8. If a pendulum is allowed to oscillate in vacuum, its time period will
   (a) decrease (b) increase
   (c) remain same (d) none of these
9. Kinetic energy of the bob of a simple pendulum is maximum
   (a) at the mean position
   (b) at the extreme left position
   (c) at the extreme right position
   (d) none of these
10. If the string of a pendulum were cut when the bob is at its central position, the bob would fall to the earth due to the absence of the
    (a) force of buoyancy
    (b) force of deformation
    (c) force exerted by the string in the downward direction
    (d) force exerted by the string in the upward direction
11. Though the forces are balanced at the mean position, even then the bob crosses over to the other extreme position after being released. This is due to
    (a) inertia of the bob
    (b) potential energy of the bob
    (c) velocity of the bob
    (d) none of these
12. If the mass of a pendulum is doubled, the time period
    (a) becomes double (c) becomes 4 times
    (b) becomes half (d) remains the same

13. When the bob is in the central position, the forces are
    (a) balanced
    (b) unbalanced
    (c) sometimes balanced and sometimes unbalanced
    (d) none of these
14. The phenomenon in which the amplitude of oscillation of a pendulum decreases gradually is called,
    (a) decay period of oscillation
    (b) damping
    (c) building up of oscillation
    (d) maintained oscillation
15. The graph between L and T is

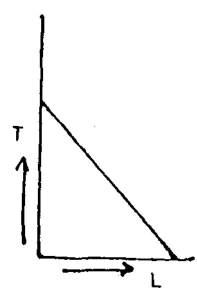


(a)

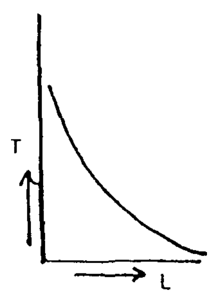


(b)

Fig. 4.2 (a) (b)



(c)



(d)

Fig. 4.2 (c) (d)

16. The length of a pendulum is doubled and the mass of its bob is halved. Its time period would
    (a) become double
    (b) become half
    (c) become $\sqrt{2}$ times
    (d) remain the same
17. A pendulum having a period of oscillation of 2 seconds is taken on a planet where g is four times that on the earth. The period of the pendulum would be
    (a) 2 s (b) 1 s (c) 4 s (d) $2\sqrt{2}$ s
18. Potential energy of the bob is maximum
    (a) at the mean position
    (b) at the extreme positions
    (c) between the mean position and extreme positions
    (d) none of these
19. The force which tries to bring the body back to its mean position is called
    (a) deforming force
    (b) restoring force
    (c) gravitational force
    (d) buoyant force
20. For a given length of a pendulum, the time period is maximum
    (a) on the surface of the earth
    (b) on the surface of the moon
    (c) at the centre of the earth
    (d) none of these

True or False Statements

1. The period of oscillation of a simple pendulum varies directly with the square root of the length.
2. The period of oscillation of a simple pendulum is inversely proportional to the square root of acceleration due to gravity.
3. The time period of a simple pendulum depends upon the amplitude of vibration.
4. When a simple pendulum is taken from the surface of the earth to the top of a mountain, its time period will increase.
5. Centre of suspension and the point of oscillation are same.
6. The graph between length and time period of a simple pendulum is a straight line.

7. The 'time period is smaller' means that pendulum will vibrate slowly.
8. The period of oscillation of a simple pendulum is directly proportional to the mass of the bob.
9. Restoring force is not required to produce to and fro motion.
10. If a pendulum clock be taken from the equator to the poles, time period increases.
11. The effective length of a pendulum is the distance between the point of suspension and the centre of gravity of the bob.
12. When the bob is at its extreme position, the forces acting on it are unbalanced.
13. When a force acts in the direction of motion the speed of the body increases.
14. When the bob of a pendulum is at its extreme position, the forces acting on it are unbalanced.
15. A pendulum whose time period is 4 s is called second's pendulum.
16. A stretched spring always tends to return to its normal length due to restoring force.
17. The oscillation of a simple pendulum are isochrons.
18. The force which tries to bring the body back to its normal position is called the deforming force.
19. The speed of the bob decreases when we go from the extreme position to the mean position.
20. The straight line graph between L and T^2 confirms that $L \propto T^2$.

ANSWERS (OBJECTIVE EVALUATION)

1. (b)	2. (b)	3. (c)	4. (d)	5. (a)	6. (a)	7. (a)	8. (a)	9. (a)
10. (c)	11. (a)	12. (d)	13. (d)	14. (b)	15. (b)	16. (c)	17. (b)	18. (b)
19. (b)	20. (b)							

ANSWERS (TRUE/FALSE)

1. T	2. T	3. F	4. T	5. F	6. F	7. F	8. F	9. F
10. F	11. T	12. T	13. T	14. T	15. F	16. T	17. T	18. F
19. F	20. T							

UNIT FIVE
WAVES

REVIEW CONCEPTS

Waves can be defined as disturbances that travel through a medium due to the repeated periodic motion of the particles of the medium about their mean positions, the motion being handed over from one particle of the medium to the next.

Periodic motion is a type of motion which repeats itself after definite intervals of time. For example, the motion of the moon around the earthis an example of periodic motion.

Simple harmonic motion (SHM) is a periodic motion in which a particle moves to and fro about a fixed point, such that its acceleration is directly proportional to its displacement from the fixed point and is always directed towards it. The motion of a simple pendulum is an example of SHM.

Transverse wave motion occurs when the particles of the medium vibrate about their mean positions, at right angles to the direction of wave propagation.

Longitudinal wave motion occurs when the particles of the medium vibrate about their mean positions, along the direction of wave propagation.

Amplitude is the maximum displacement of a particle from its mean position.

Frequency (ν) is the number of vibrations made by the vibrating particle in one second.

Time period (T) is the time taken to complete one full vibration.

Wavelength (λ) is the distance between two nearest particles which are in the same state of vibration.

Velocity of waves (v) is the product of wavelength and frequency.

Characteristics of wave motion

(a) Each particle takes energy from its preceding particle and transfers it to the next particle and so on.

(b) It is only the energy which is being transferred and not the particles themselves

(c) All waves travel with the same speed in the same medium

(d) Velocity of the waves is different than the velocity of particles.

A ***pulse*** is a disturbance which is sudden and is of a very short duration of time.

Audible range is the range of frequency which can be heard by human beings, i.e., 20 Hz to 20,000 Hz.

Formulae

1. Frequency and time period are related as

$$\nu = \frac{1}{T}$$

2. Velocity of a wave is given as

$$v = \nu \times \lambda \quad \text{or} \quad \nu = \frac{v}{\lambda} \quad \text{or} \quad \lambda = \frac{v}{\nu}$$

where λ = wave length
v = velocity and
ν = frequency

3. Frequency

$$\nu = \frac{\text{Number of vibrations}}{\text{Time taken}}$$

4. $v = \frac{\lambda}{T}$ where T = Time period and
λ = wavelength

NUMERICAL PROBLEMS (SOLVED)

EXAMPLE 1 Sound travels with a speed of about 330 m/s. What is the wavelength of sound whose frequency is 550 Hz. ?

Solution: Given,

Speed of sound (v) = 330 m/s
Frequency (ν) = 550 Hz

To calculate : Wavelength (λ) = ?

Formula to be used : $v = \nu \times \lambda$

$$\therefore \quad \lambda = \frac{v}{\nu}$$

Substituting the given values of v and ν we get

$$\lambda = \frac{330}{550} = 0.6 \text{ m}$$

EXAMPLE 2 If the period of small ripples on water is 0.1 s and their wavelength is 5.0 cm, what is speed of the waves ?

Solution: Given,

Time period (T) = 0.1 s

Wavelength (λ) = 5.0 cm

To calculate : Speed of the waves (v) = ?

Formula to be used : $v = \frac{\lambda}{T}$

Substituting the given values of λ and T

$$v = \frac{5.0}{0.1} = 50 \text{ cm/s.}$$

or $v = 0.5$ m/s

EXAMPLE 3 What is the frequency of a wave whose time period is 0.05 s ?

Solution: Given,

Time period (T) = 0.05 s

To calculate : Frequency (ν) = ?

Formula to be used : $\nu = \frac{1}{T}$

$$\therefore \quad \nu = \frac{1}{0.05} = \frac{100}{5}$$

=> $\nu = 20$ Hz

EXAMPLE 4 If 25 waves were produced per second. What is the frequency in Hz ?

Solution: Given,

No. of waves = 25

Time (t) = 1 s

To calculate : Frequency (ν) = ?

Formula to be used : $\nu = \frac{\text{Number of waves}}{\text{Time taken}}$

$$\nu = \frac{25}{1} = 25 \text{ Hz}$$

EXAMPLE 5 What would be the time period of the wave whose

Solution: Given,

Frequency (ν) $= 6$ KHz

$= 6 \times 10^3$ Hz

To calculate : Time period (T) $= ?$

Formula to be used : $T = \dfrac{1}{\nu}$

$$T = \frac{1}{6 \times 10^3}$$

$$= \frac{1 \times 10^{-3}}{6}$$

$$T = 0.16 \times 10^{-3} \text{ s}$$

EXAMPLE 6 A source is producing 15 waves in 3.0 s. The distance between a crest and a trough is 10.0 cm. Find

(a) the frequency

(b) the wavelength

(c) the velocity of the wave

Solution: Given,

No. of waves $= 15$

Time (t) $= 3.0$ s

Distance between a crest and a trough ($\lambda/2$) $= 10.0$ cm

To calculate : (i) Frequency (ν) $= ?$

(ii) Wavelength (λ) $= ?$

(iii) Velocity (v) $= ?$

Formula to be used : (i) $\nu = \dfrac{\text{Number of vibrations}}{\text{Time taken}}$

(ii) $\lambda =$ distance between either two consecutive crests or troughs

(iii) $v = \nu \times \lambda$

(i) To find $\nu = \dfrac{15}{3.0} = 5$ Hz

(ii) Wavelength $\lambda = \dfrac{\lambda}{2} = 10.0$

$\lambda = 20.0$ cm

(iii) Velocity (v) $= \nu \times \lambda$

$v = 5 \times 20 = 100$ cm/s

EXAMPLE 7 A body is vibrating 6000 times in one minute. If the velocity of sound in air is 360 m/s, find (i) frequency of the vibration in Hz (ii) wavelength of the sound produced.

Solution: Given,

Number of vibrations = 6000

Time (t) = 1 min = 60 s

Velocity (v) = 360 m/s

To calculate : (i) Frequency (ν) = ?

(ii) Wavelength (λ) = ?

Formula to be used : (i) $\nu = \dfrac{\text{Number of vibrations}}{\text{Time taken}}$

(ii) $v = \nu \times \lambda \Rightarrow \lambda = \dfrac{v}{\nu}$

(i) To find 'ν' $\quad \nu = \dfrac{6000}{60} = 100$ Hz

(ii) To find 'λ' $\quad \lambda = \dfrac{360}{100} = 3.60$ m

EXAMPLE 8 Calculate the wavelength in air, of a note of frequency 400 Hz when the velocity of sound in air is 330 m/s.

Solution: Given,

Frequency (ν) = 400 Hz

Velocity (v) = 330 m/s

To calculate : Wavelength (λ) = ?

Formula to be used : $\lambda = \dfrac{v}{\nu}$

Substituting the given values

$$\lambda = \frac{330}{400} = 0.825 \text{ m}$$

EXAMPLE 9 In a ripple tank 10 full ripples are produced in one second. If the distance between a trough and the next crest is 12.0 cm, find out (i) frequency (ii) wavelength and (iii) velocity of the wave.

Solution: Given,

Number of ripples (wave) = 10

Time (t) = 1 s

Distance between a crest and a trough ($\lambda/2$) = 12 cm

To calculate : (i) Frequency (ν) = ?

(ii) Wavelength (λ) = ?

(iii) Velocity (v) = ?

Formula to be used : (i) $\nu = \dfrac{\text{Number of vibrations}}{\text{Time taken}}$

(ii) λ = Twice the distance between a crest and a trough

(iii) Velocity (v) = $\lambda \times \nu$

(i) To find 'ν' $\nu = \dfrac{\text{Number of vibrations}}{\text{Time taken}}$

$$\nu = \frac{10}{1} = 10 \text{ Hz}$$

(ii) To find 'λ' $\lambda = 2 \times 12.0 = 24.0$ cm

(iii) To find 'v' $v = \nu \times \lambda = 10 \times 24.0 = 240$ cm/s

EXAMPLE 10 A longitudinal wave is travelling along a spiral spring with a velocity of 1 m/s. If the time period of the wave is 0.1 s, what is the wavelength ?

Solution: Given,

Velocity (v) = 1.0 m/s

Time period (T) = 0.1 s

To calculate : Wavelength (λ) = ?

Formula to be used : $\lambda = v \times T$

$\therefore$ $\lambda = 1.0 \times 0.1$

$\lambda = 1/10$ m = 0.1 m

EXAMPLE 11 Delhi Radio station (C) transmits musical programmes at 219 m wavelength and 1300 Hz frequency. Calculate the velocity of radio waves.

Solution: Given,

Wavelength (λ) = 219 m

Frequency (ν) = 1300 Hz

To calculate : Velocity (v) = ?

Formula to be used : $v = \nu \times \lambda$

Substituting the given values of ν and λ

$$v = 1300 \times 219$$

$$= 284700 \text{ m/s}$$

$$v = 2.847 \times 10^5 \text{ m/s}$$

EXAMPLE 12 The following graph shows the displacement versus distance of a pulse on a rope at two different times. Find the speed of the pulse.

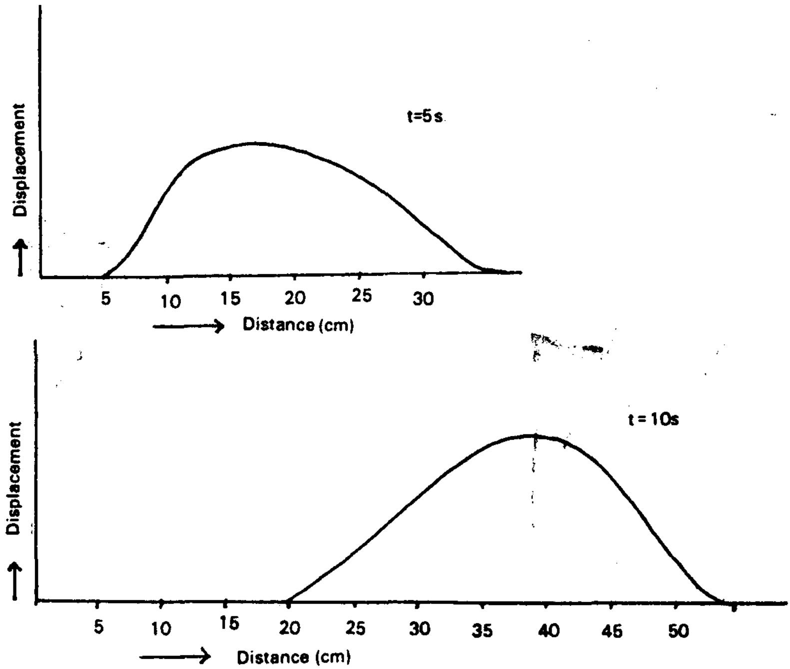


Fig. 5.1

Solution: Given,

Time for the first wave (t_1) = 5.0 s

Time for the second wave (t_2) = 10.0 s

Distance in the first case (d_1) = 15.0 cm (from graph)

Distance in the second case (d_2) = 37.5 cm (from graph)

To calculate : Speed of the pulse (v) = ?

Formula to be used : $v = \dfrac{\text{distance}}{\text{time}}$

Now, distance moved $(d) = d_2 - d_1$

$$= 37.5 - 15.0$$
$$= 22.5 \text{ cm}$$

and time taken $(t) = t_2 - t_1 = 10.0 - 5.0 = 5.0$ s

$$= \frac{22.5}{5} = 4.5 \text{ cm/s}$$

NUMERICAL PROBLEMS (UNSOLVED)

1. The frequency of a vibrating body is 500 Hz. Calculate the wavelength of the sound wave produced if the velocity of sound in air is 332.0 m/s. (Ans. 0.664 m)
2. A body vibrating with a time period of 1/2000 s, produces a wave which travels in a medium with a speed of 400 m/s. Find the wavelength. (Ans. 0.2 m)
3. In a ripple tank 20 full ripples are produced per second. The distance between the lowest point of a trough and the highest point of its nearest crest is 15.0 cm. Find (a) frequency (b) wavelength and (c) velocity. (Ans. 20 Hz, 30 cm, 600 cm/s)
4. A violin string emits sound with a frequency of 850 Hz. What is the distance between a crest and a neighbouring trough that passes through air ? What is the period of vibration ? (Speed of sound v = 340 m/s) (Ans. 0.2 m, 1/850 s)
5. Longitudinal waves travel at the speed of 10 m/s in a coiled spring. If the distance between two successive rarefactions is 10.0 cm. Find the frequency of the wave. (Ans. 100 Hz)
6. A tuning fork has a frequency of 512 Hz and it produces a sound wave of wavelength 0.65 m. Calculate the velocity of the sound wave in air. (Ans. 332.8 m)
7. An ultrasonic wave is sent from a ship towards the bottom of the sea. It is found that the time interval between sending and receiving the wave is 1.5 s. If the velocity of sound is 1400 m/s in sea water, calculate the depth of the sea. (Ans. 1050 m)
8. An observer measures the time interval between the sighting of lightning and hearing the thunder. He finds it to be 5.0 s. If the speed of sound in air is 340 m/s, how far is the cloud from the observer ? (Ans. 1700 m)
9. A stone is dropped into a well. The sound of the splash is heard after 2.5 s. Find the depth of the well. Take velocity of sound = 330 m/s.

(Hint : Total time (t) = 2.5 s. It consists of two parts : (i) Time taken (t_1) by the stone to reach the water surface in the well and (ii) Time taken (t_2) by the sound to cover a distance equal to the depth of the well).

(To calculate t_1, use $S = 1/2gt_1^2$ and to calculate t_2, use $t = S/v$) (Ans. 28.6 m)

10. The lowest pitch detectable as sound by an average human ear corresponds to 20 Hz and the highest to 20,000 Hz. What is the wavelength of each in air ? Take velocity of sound as 330 m/s. (Ans. 16.5 m and 1.65 cm)

OBJECTIVE EVALUATION

1. In which of the following mediums will sound travel the fastest?
   (a) solid (c) liquid
   (b) both solid and liquid (d) gas
2. Sound waves in air are ____________ waves.
   (a) longitudinal (c) transverse
   (b) radio (d) electromagnetic
3. Sound waves cannot pass through
   (a) a solid liquid mixture (c) a liquid gas mixture
   (b) an ideal gas (d) a perfect vacuum
4. Out of the following, which frequencies are not clearly audible to the human ear ?
   (a) 30 Hz (c) 300 Hz
   (b) 30,000 Hz (d) 3000 Hz
5. The frequency of sound waves can be expressed in
   (a) Hz (c) s^{-1}
   (b) cycles/second (d) all the above
6. The distance between two consecutive crests is L, then the wavelength is given by
   (a) $L/2$ (c) $4L$
   (b) $2L$ (d) L
7. If the distance between a crest and its consecutive trough is L, then the wavelength is given by
   (a) $L/2$ (c) $4L$
   (b) L (d) $2L$

8. The product of the time period of a wave and its frequency is
   (a) infinite
   (b) zero
   (c) more than unity but less than infinity
   (d) unity
9. A wave completes 20 vibrations in 2.5 s, its frequency is
   (a) 20 Hz
   (b) 8 Hz
   (c) 200 Hz
   (d) 50 Hz
10. Imagine a cannon being fired on the surface of the moon. Then
    (a) the sound will be heard at the surface of the earth during all seasons
    (b) the sound will not be heard at the surface of the earth
    (c) the sound will be heard at the surface of the earth during the rainy season
    (d) no sound will be heard on the earth or on the moon
11. Sound waves are
    (a) transverse mechanical waves
    (b) longitudinal mechanical waves
    (c) either (a) or (b)
    (d) none of these
12. The speed of a sound wave in a given medium is
    (a) directly proportional to its frequency
    (b) inversely proportional to its frequency
    (c) directly proportional to the square of its frequency
    (d) independent of its frequency
13. Supersonic means
    (a) frequencies less than 20 Hz
    (b) same as ultrasonic
    (c) frequencies much more than that of ultrasonics
    (d) same as infrasonics
14. The frequency of a wave is 5 Hz. It refers to (type of wave)
    (a) ultrasonics
    (b) microwaves
    (c) infrasonics
    (d) radio waves
15. When a vibrating tuning fork is placed on a table, a large sound is heard. This is due to
    (a) forced vibrations
    (b) resonance
    (c) beats
    (d) reflection

16. A wave completes 24 cycles in 0.8 s. The frequency of the wave is
    (a) 30 Hz (b) 8 Hz (c) 24 Hz (d) 12 Hz
17. The time period of the above wave would be
    (a) 1/30 s (b) 30 s (c) 1/24 s (d) none of these
18. The relation between frequency and wavelength is given by
    (a) $v = \nu \times \lambda$ (b) $v = \frac{\lambda}{\nu}$ (c) $v = \frac{\nu}{\lambda}$ (d) $v = \frac{T}{\lambda}$
19. Frequency and time period are related as
    (a) $\nu \times T = 1$ (b) $\frac{\nu}{T} = 1$ (c) $\nu = T^2$ (d) $\nu = T^{-2}$
20. A body produces sound only if it is
    (a) made of steel (c) plucked
    (b) made of glass (d) vibrating
21. If the time period of a wave increases, its frequency will
    (a) increase (c) remain the same
    (b) decrease (d) first increases then decreases
22. A pulse is a wave
    (a) of high duration
    (b) of short duration
    (c) which travels in vacuum only
    (d) which travels in solids only
23. When we pluck the wire of a sitar, the waves produced in the wire are
    (a) longitudinal
    (b) transverse
    (c) sometimes longitudinal and sometimes transverse
    (d) electromagnetic
24. When we pluck the wire of a sitar, the waves produced in the air are
    (a) longitudinal
    (b) transverse
    (c) sometimes longitudinal and sometimes transverse
    (d) electromagnetic

25. A crest is the point of
    (a) zero displacement (c) minimum displacement
    (b) maximum displacement (d) none of these

26. A trough is a point of
    (a) zero displacement (c) minimum displacement
    (b) maximum displacement (d) none of these

27. Two particles having the same phase must be at
    (a) one crest and one trough
    (b) one crest and the mean position
    (c) one trough and the mean position
    (d) two crests

28. If the frequency of a wave is doubled, its wavelength
    (a) becomes doubled (c) becomes half of the original
    (b) remains same (d) none of these

29. An anchored boat is rocked by waves whose crests are 100 m apart and whose velocity is 25 m/s. How often do the crests reach the boat.
    (a) 0.25 s (b) 4 s (c) 75 s (d) 2500 s

30. Figure 5.2 shows that the shape of a part of a long string in which transverse waves are produced. Which pair of particles are in phase?
    (a) A and G (b) D and G (c) B and E (d) C and I

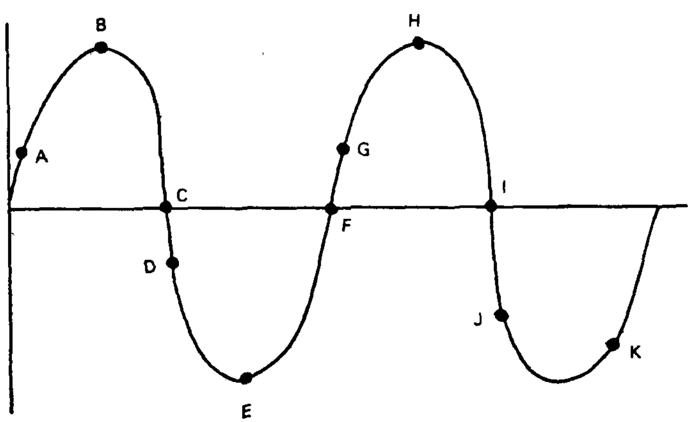


Fig. 5.2

True or False Statements

1. All sound waves have the same wavelength
2. All sound waves are caused by vibrations
3. In a metal, the sound waves that propagate are always transverse.
4. Wavelength is measured in Hertz.
5. Since sound waves can travel through air, and air can transmit only transverse waves, it follows that sound travels as transverse waves.
6. Light is a longitudinal wave.
7. Wave velocity is equal to particle velocity
8. Wave motion is different from heat conduction in one respect that the latter needs a temperature difference whereas the former does not.
9. Transverse waves cannot propagate in a gas.
10. Wavelength is the distance between two particles of the same medium in the opposite phase.
11. Frequency of sound waves can be expressed in cycles per second.
12. Since liquids and solids possess elastic properties, so transverse wave motion is possible in both.
13. Momentum is transported along with a wave.
14. Louder sound travels faster in air than a feeble sound.
15. The frequency of sound of a man is greater than that of a woman.

ANSWERS (OBJECTIVE EVALUATION)

1. (a)	2. (a)	3. (d)	4. (b)	5.(d)	6. (d)	7. (d)	8. (d	9. (b)
10. (b)	11. (b)	12. (a)	13. (b)	14. (c)	15. (a)	16. (a)	17. (a)	18. (a)
19. (a)	20. (d)	21. (b)	22. (b)	23. (b)	24. (a)	25. (b)	26. (c)	27. (d)
28. (c)	29 (b)	30 (a), (d)						

ANSWERS (TRUE/FALSE)

1. T	2. T	3. F	4. F	5. F	6. F	7. F	8. T	9. T
10. F	11. T	12. T	13. T	14. F	15. T			

UNIT SIX
WORK AND ENERGY

REVIEW CONCEPTS

Energy is the ability of a body to do work. In the SI system the unit of energy is the joule.

Kinetic Energy of a body is due to the motion of a body.

Potential Energy of a body is by virtue of position or configuration of the body.

Mechanical Energy is the sum of the potential energy and the kinetic energy of an object.

Law of Conservation of Energy states that energy can neither be created nor be destroyed. It can only be transferred from one form to another.

Transformation of Energy means change or conservation of energy from one form to another.

Work is said to be done if a body moves through a certain distance under the application of a force. The work done is equal to the product of force and the distance travelled in the direction of the force. If we denote the work done, force applied and the distance moved in the direction of force as W, F and S respectively, then $W = F \times S$.

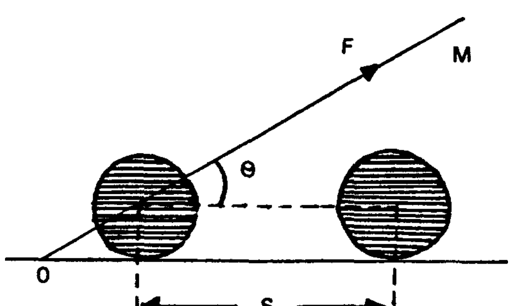


Fig. 6.1 Work done by a force

Now suppose the force is applied along the direction OM. The component of F along the ground, as shown in Fig. 6.1 will be $F \cos \theta$, where θ is the angle that F makes with the ground. If the body moves through a distance S, then the work done will be

$$W = (F \cos \theta) S$$

In this case the work done is less than FS because only a fraction of the force, F, does the work. Thus, we can define work done in the following manner. The work done by a force is equal to the product of the component of the force along the direction of motion of the object and the distance through which the point of application of the force moves. The unit of work done is the joule. On joule of work is done when a force of one newton acts on a body and moves it through a distance of one metre in the direction of application.

Power is the rate of doing work.

The SI unit of power is the watt.

Formulae

1. Work done W = Force × distance

$$= Fd$$

where F = force applied and

d = displacement

2. Work done $W = Fd \cos \theta$

where θ is the angle between the direction of the force and the direction of motion of the body.

3. Kinetic energy (KE) $= \frac{1}{2} mv^2$

where m = mass of the body and

v = velocity

4. Potential energy (PE) $= mgh$

where m = mass of the body

g = acceleration due to gravity and

h = height

5. Also from $\frac{1}{2} mv^2 = \text{KE}$

$$v = \sqrt{\frac{2 \times \text{KE}}{m}}$$

6. Work done = change in KE

$$= \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$

where v = final velocity and
u = initial velocity

7. Power (P) $= w/t$
where w = work done and
t = time taken

8. Escape velocity $v = \sqrt{2R_e g}$
where R_e = radius of the earth and
g = acceleration due to gravity

NUMERICAL PROBLEMS (SOLVED)

EXAMPLE 1 A man drops a 10 kg rock from the top of a 5.0 m ladder. What is its KE, when it reaches the ground? What is its speed just before it reaches the ground ?

Solution: Given,

Mass of the rock (m) = 10 kg
Height (h) = 50 m
Acceleration due to gravity (g) = 9.8 m/s^2

To calculate : (i) Kinetic Energy (KE) = ?
(ii) Speed (v) = ?

Formula to be used : (i) KE $= \frac{1}{2}mv^2$

But when the body reaches the ground the whole of its potential energy gets converted into kinetic energy

PE at the top of the ladder = KE on the ground

$$mgh = \text{KE on the ground} \quad \text{(i)}$$

$$mgh = \frac{1}{2}mv^2$$

or $$gh = \frac{1}{2}v^2$$

=> $$v = \sqrt{2gh}$$

Substituting the values of g and h

$$v = \sqrt{2 \times 9.8 \times 5}$$
$$v = 7\sqrt{2} \text{ m/s}$$

Also from equation (i)

$$10 \times 9.8 \times 5 = \text{KE}$$
$$\text{KE} = 490 \text{ Joule.}$$

EXAMPLE 2 A car weighing 1000 kg and travelling at 30 m/s stops at a distance of 50 m accelerating uniformly. What is the force exerted on it by the brakes ? What is the work done by the brakes ?

Solution: Given,

Mass of the car (m) = 1000 kg

Initial speed (u) = 30 m/s

Final speed (v) = 0 (since the car stops finally)

Distance (d) = 50 m

To calculate : (i) Force (F) = ?

(ii) Work (W) = ?

Formula to be used : (i) work done = change in KE

$$W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$

(ii) Work done = Force × displacement

=> $$\text{Force} = \frac{\text{Work}}{\text{Displacement}} = \frac{W}{d}$$

(i) To calculate work done (W)

$$W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$

substitute the value of 'm', 'u' & 'v' in this equation

$$W = \frac{1}{2}(1000)(0)^2 - \frac{1}{2}(1000)(30)^2$$
$$= 0 - \frac{1}{2}(1000)(900)$$
$$W = -450000 \text{ Joules}$$

(significance of the negative sign is that the work is done on the car by the brakes)

(ii) To calculate force (F)

$$F = \frac{W}{d}$$
$$F = -\frac{450000}{50}$$
$$F = -9000 \text{ N}$$

(Again negative sign indicates that it is a retarding force)

EXAMPLE 3 A load of mass 100 kg is pulled up by 5.0 m. Calculate the work done. (Take $g = 9.8 \text{ m/s}^2$)

Solution: Given,

Mass (m) = 100 kg

Height(h) or Distance(d) = 5.0 m

Acceleration due to gravity (g) = 9.8 m/s

To calculate : Work done (W) = ?

Formula to be used : $W = mgh$

Substituting the given values of m, g and h we get,

$$W = 100 \times 9.8 \times 5$$

$$W = 4900 \text{ Joules}$$

EXAMPLE 4 The weight of a man is 300 N. Calculate the amount of work he does in climbing the second floor 7.0 m high of a building.

Solution: Given,

Weight (Force) F = 300 N

Height (Distance) d = 7.0 m

To calculate : Work done (W) = ?

Formula to be used : $W = Fd$

$$W = 300 \times 7.0$$

$$W = 2100 \text{ Joules}$$

EXAMPLE 5 A ball of mass 200 g falls from a height of 2.0 m. What is the KE of the ball when it reaches the ground? Take $g = 9.8 \text{ m/s}^2$.

Solution: Given,

Mass of the ball (m) = 200 g = 200×10^{-3} kg

Height or distance (d) = 2.0 m

Acceleration due to gravity (g) = 9.8 m/s^2

To calculate : KE of the ball when it reaches the ground = ?

Formula to be used : PE at the top = KE at the ground

$$\text{PE} = mgh$$

$$= (200 \times 10^{-3})\ (9.8)\ (2.0)$$

$$\text{PE} = 3.92 \text{ Joules}$$

KE of the ball when it reaches the ground is the same as PE at the top

$$\text{KE} = 3.92 \text{ Joules}$$

EXAMPLE 6 A body of mass 2 kg falls from rest. What will be its KE during the fall at the end of 2 second ? (Take $g = 10$ m/s^2)

Solution: Given,

Mass (m) = 2.0 kg

Initial velocity (u) = 0

Time (t) = 2.0 s

Acceleration due to gravity (g) = 10 m/s^2

To calculate : KE = ?

Formula to be used : $KE = \frac{1}{2}mv^2$

But we are not given v, so our first problem is to calculate v by using the formula

$$v = u + gt$$
$$v = 0 + (10)(2)$$
$$v = 20 \text{ m/s}$$

Now put this value of v and the value of m for KE we get,

$$KE = \frac{1}{2}(2.0)(20)^2$$
$$KE = 400 \text{ J}$$

EXAMPLE 7 A body of mass 2 kg thrown vertically upwards with an initial velocity of 20 m/s. What will be its potential energy at the end of 2.0 s (Take $g = 10$ m/s^2)

Solution: Given,

Mass (m) = 2.0 kg

Initial velocity (u) = 20 m/s Time (t) = 2.0 s

Solution: Given, Mass (m) = 2.0 kg

Initial velocity (u) = 20 m/s

Time (t) = 2.0 s

Acceleration due to gravity (g) = 10 m/s^2

To calculate : Potential Energy (PE) = ?

Formula to be used : $PE = mgh$

Now in this question we are not given the height up to which the body rises. So we will first find out h using the equation

$$h = ut - \frac{1}{2}gt^2$$

(Here we have taken 'g' negative since the motion of the body is retarded in going up.)

$$h = (20 \times 2) - \frac{1}{2}(10)(2)^2$$

$$= 40 - 20 = 20 \text{ m}$$

$$PE = mgh$$

$$= 2 \times 10 \times 20 = 400 \text{ Joules}$$

EXAMPLE 8 Two bodies of equal masses move with uniform velocities v and $2v$ respectively. Find the ratio of their kinetic energies.

Solution: Given, Let velocity of the body A = v

and Velocity of the body B = $2v$

Let mass of the body A = m

and Mass of the body B = m (since mass is same)

To calculate : $\dfrac{\text{KE of A}}{\text{KE of B}} = ?$

Formula to be used : $\text{KE} = \dfrac{1}{2}mv^2$

$$\text{KE of body A} = \frac{1}{2}m(v)^2$$

and $$\text{KE of body B} = \frac{1}{2}m(2v)^2$$

$$= 2mv^2$$

$$\frac{\text{KE of A}}{\text{KE of B}} = \frac{\frac{1}{2}mv^2}{2mv^2} = \frac{1}{4}$$

or KE of A : KE of B : 1 : 4

EXAMPLE 9 A pendulum is pulled to one side until its bob is 10 cm higher than when weighing vertically and is then released. What is its speed as it passes through the mid-point of swing.

Solution: Given,

Height (h) = 10 cm = 10 × 10 m

Acceleration due to gravity (g) = 9.8 m/s

To calculate : Speed at A (v) = ?

Formula to be used : $v = \sqrt{2gh}$

Substituting the given values

$$v = \sqrt{2 \times 9.8 \times 10 \times 10^{-2}}$$

$$v = 1.4 \text{ m/s}$$

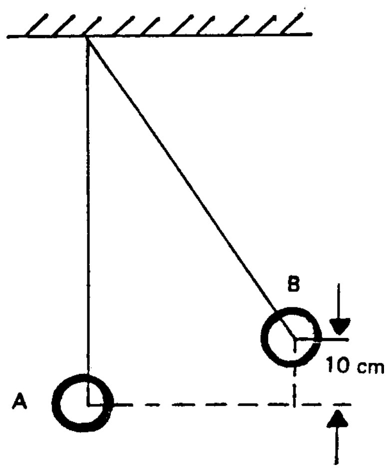


Fig. 6.2

EXAMPLE 10 A box weighing 40 N slides down from the top of an inclined plane making an angle of 30° with the horizontal. Calculate the work done by the force of gravity in moving the box 2.0 m long along the plane. Assume that the force of friction is zero.

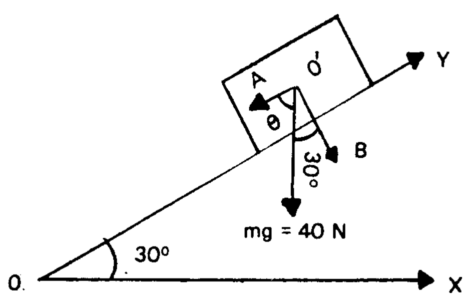


Fig. 6.3

Solution: Given,

Force acting downward (F) = 40 N

Distance (d) = 2.0 m

Angle $\theta = 90^\circ - 30^\circ = 60^\circ$ (from Fig. 6.3)

To calculate : Work done (W) = ?

Formula to be used : $W = Fd\cos\theta$

$= 40 \times 2 \times \cos 60^\circ$

$= 80 \times 0.5 = 40\text{ J}$

(Please note that in this case the angle between F and d is 60°)

EXAMPLE 11 A man of mass 60 kg runs up a flight of 30 steps in 40 s. If each step is 20 cm high, calculate his power. (Take $g = 10\text{ m/s}^2$)

Solution: Given,

Mass (m) = 60 kg

Total distance (d) $30 \times 20 = 600$ cm

$= 600 \times 10^{-2}$ m

Time (t) = 40 s

Acceleration due to gravity (g) = 10 m/s^2

To calculate : Power (P) = ?

Formula to be used : $P = \dfrac{W}{t} = \dfrac{mgh}{t}$

Substituting the given values,

$$P = \frac{60 \times 10 \times 600 \times 10^{-2}}{40}$$

$$P = \frac{3600}{40} = 90\text{ Watts}$$

EXAMPLE 12 How fast should a man of 50 kg run so that his Kinetic Energy is 625 J ?

Solution: Given,

Mass (m) = 50 kg

Kinetic Energy (KE) = 625 J

To calculate : Velocity (v) = ?

Formula to be used : $\text{KE} = \dfrac{1}{2}mv^2$

$$= v^2 = 2 \times \frac{KE}{m}$$

$$v^2 = \frac{2 \times 625}{50}$$

or $$v^2 = \frac{1250}{50} \text{ or } v = \sqrt{25}$$

$$= \pm\ 5 \text{ m/s}$$

We have not considered the negative sign since it indicates the direction of motion only.

EXAMPLE 13 Calculate the power developed by a 110 kg man climbing up a vertical stairway at the rate of 2.0 m/s. (Take $g = 9.8 \text{ m/s}^2$)

Solution: Given,

Mass (m) = 110 kg

Acceleration due to gravity (g) = 9.8 m/s^2

Distance covered in 1 sec (d) = 2.0 m

To calculate : Power (P) = ?

Formula to be used : $P = \frac{W}{t}$

But $W = mgd$

$$P = \frac{mgd}{t}$$

Substituting the given values,

$$P = \frac{110 \times 9.8 \times 2}{1} = 2.56 \text{ Watts}$$

EXAMPLE 14 A block of 20 kg mass is pulled up a slope by a applying a force acting parallel to the slope. If the slope makes an angle of 30° with the horizontal. Calculate the work done in pulling the load up a distance of 3.0 m. What is the increase in potential energy of the block ? Assume the force of friction is zero. (Take $g = 10$ N/kg)

Solution: Given,

Mass (m) = 20 kg

g = 10 N/kg

Distance (d) = 3.0 m

Angle = 30°

To calculate : (i) Work done (W) = ?

(ii) Increase in PE = ?

Formula to be used : (i) $W = Fd = mgd$

(ii) $PE = mg \times h$

(i) to find out W

$$W = mgd$$
$$= 20 \times 10 \times 3 = 600 \text{ Joules}$$

(ii) to calculate change in PE

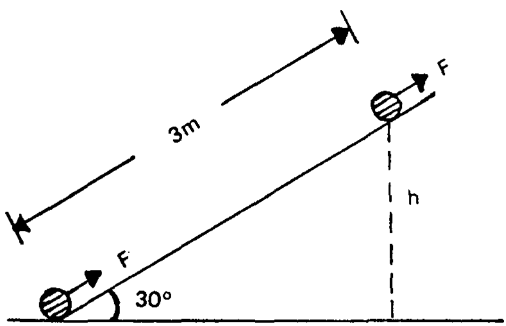


Fig. 6.4

From the Fig. 6.4, $\frac{h}{3} = \sin 30°$

or $h = 3 \sin 30°$

$$= 3 \times \frac{1}{2} = \frac{3}{2} \text{ m}$$

Now substituting this value of h, m and g we get,

$$PE = 20 \times 10 \times \frac{3}{2}$$
$$PE = 300 \text{ Joules}$$

Since initial PE (at the ground) is zero, increase in PE = 300 J

EXAMPLE 15 The speed of a bicycle decreases from 18 to 9 km/h. If the total mass of the cyclist including the bicycle is 70 kg, calculate the work done in overcoming the friction offered by the brakes and the road. Does the KE of the system also reduce to half its initial value ?

Solution: Given,

Mass (m) = 70 kg

Initial velocity(u) = 18 km/h

$$= \frac{18 \times 1000}{3600} = 5 \text{ m/s}$$

Final velocity (v) = 9 km/h

$$= \frac{9 \times 1000}{3600} = 2.5 \text{ m/s}$$

To calculate : (i) Work done (W) = ?

(ii) Ratio of initial work to final work W_1/W_2 = ?

Formula to be used : Work done (W) = Change in KE

(i) Work done

$$(W) = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$

$$= \frac{1}{2}(70)(2.5)^2 - \frac{1}{2}(70)(5.0)^2$$

$$= 656.25 \text{ Joules}$$

(ii) Initial work done (W_1) = 656.25 Joules

Final work done

$$(W_2) = \frac{1}{2} \times 70 \times (5.0)^2$$

$$= 35 \times 25 = 875 \text{ Joules}$$

$$\frac{W_1}{W_2} = \frac{656.25}{875} = \frac{3}{4}$$

It shows that the KE is reduced to 3/4th of its initial value.

EXAMPLE 16 A man weighing 60 kg is ascending a ladder 10 m long making an angle 30° with the horizontal. Calculate the work done by him against gravity.

Solution: Given,

Mass (m) = 60 kg

Angle made by the ladder with the vertical

$= 90° - 30° = 60°$

Length of the ladder = 10 m

To calculate : Work done (W) = ?

Formula to be used : $W = mgh$

But h = vertical distance moved by the man

$= d \cos\theta$

$= 10 \times \cos 60°$

$$= 10 \times \frac{1}{2} = 5.0 \text{ m}$$

From $W = mgh$ we get

$$W = 60 \times 9.8 \times 5 = 2940 \text{ J}$$

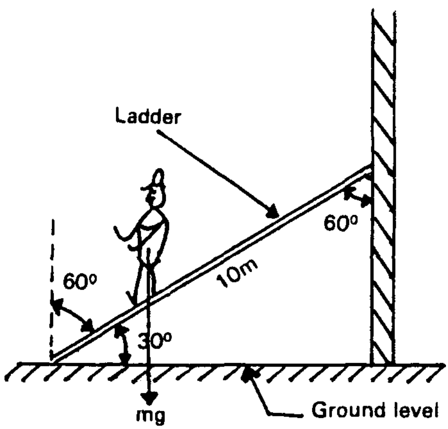


Fig. 6.5

EXAMPLE 17 On a level road, a scooterist applies brakes to slow down from a speed of 36 to 18 km/h. Find the work done by the brakes. The mass of the scooter is 86 kg and the mass of the scooterist and petrol is 64 kg.

Solution: Given,

Total Mass $(m) = 86 + 64 = 150$ kg

Initial speed $(u) = 36$ km/h

$$= \frac{36 \times 1000}{3600} = 10 \text{ m/s}$$

$$\text{Final speed } (v) = \frac{18 \times 1000}{3600} = 5 \text{ m/s}$$

To calculate : Work done $(W) = ?$

Formula to be used : $W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

$$W = \frac{1}{2}(150)(5)^2 - \frac{1}{2}(150)(10)^2$$

$$W = -5625 \text{ J}$$

Negative sign indicates that the work is done on the scooter.

EXAMPLE 18 One coolie A takes 1 min. to raise a box of mass m through a height of 2.0 m. Another coolie B takes 30 s for the same job. Which one has greater power and which one uses greater energy?

Solution: Given,

Height (h) = 2.0 m

Time for coolie A (t_1) = 1 min = 60 s

Time for coolie B (t_2) = 30 s

Mass of the box (m) = m

To calculate : (i) Power (P_1) for coolie A = ?

(ii) Power (P_2) for the coolie B = ?

(iii) Energy for coolie A & B = ?

Formula to be used : Power (P) $= \dfrac{\text{Work}}{\text{Time}} = \dfrac{mgh}{t}$

$$\text{Power } (P_1) \text{ for coolie A} = \frac{m \times g \times 2}{60}$$

$$P_1 = \frac{2\,mg}{60} \text{ Watt}$$

Similarly, $$\text{Power } (P_2) \text{ for coolie B} = \frac{mg \times 2}{30}$$

$$P_2 = \frac{2mg}{30}$$

comparing P_1 and P_2 we see that $P_2 > P_1$ i.e., the power of coolie B is more.

The energy spent in both the cases is same.

EXAMPLE 19 A box weighing 15 N slides down from the top of an inclined plane making an angle of 30° with the horizontal. Calculate the work done by the force of gravity in moving the box 5.0 m along the plane. (Take $g = 10\ \text{m/s}^2$.) Also assume that the force of friction is zero.

Solution: Given,

Force (F) = 15 N

Distance (d) = 5.0 m

Angle θ = 30°

To calculate : Work done (W) = ?

Formula to be used : $W = (F \sin \theta) \times d$

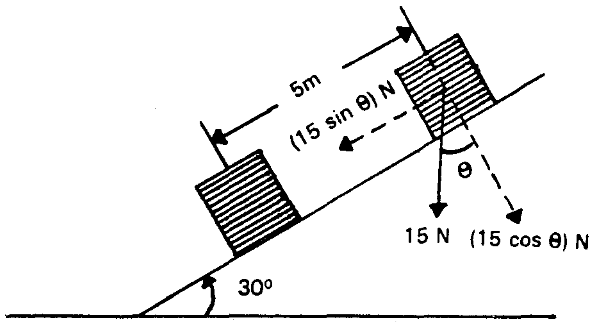


Fig. 6.6

[($F \sin \theta$) is the component of the weight along the inclined plane is along the direction of motion]

$$W = (15 \times \sin 30^\circ \times 5$$

$$= 15 \times \frac{1}{2} \times 5 = 37.5 \text{ J}$$

EXAMPLE 20 A bullet moving with a velocity of 300 m/s is just able to pierce a block of wood 2.0 cm thick. What would be its velocity if it is required to pierce a block of wood (same type) 18 cm thick ?

Solution: Given,

Thickness (d_1) $= 2.0 \text{ cm} \times 10^{-2}$ m

Thickness (d_2) $= 18.0 \text{ cm} = 18 \times 10^{-2}$ m

Velocity (v_1) $= 300$ m/s

To calculate : Velocity (v_2) = ?

Formula to be used : Work done = Kinetic Energy

$$W = \frac{1}{2} mv^2$$

i.e.,

$$Fd = \frac{1}{2} mv^2$$

Case I

$$F \times \frac{2}{100} = \frac{1}{2} m \times (300)^2 \qquad \text{(i)}$$

Case II

$$F \times \frac{18}{100} = \frac{1}{2} m \times (v_2)^2 \qquad \text{(ii)}$$

Divide (ii) by (i)

$$\frac{F \times 18 \times 100}{F \times 2 \times 100} = \frac{mv_2^2}{m(300)^2}$$

=> $$\frac{18}{2} = \frac{v_2^2}{(300)^2}$$

or $$v_2^2 = \frac{18 \times 90000}{2}$$

$$v_2 = 900 \text{ m/s}$$

NUMERICAL PROBLEMS (UNSOLVED)

1. Two unequal masses have the same KE. Prove that the momentum of the heavier body is more.
2. Two unequal masses have the same momentum. Prove that the heavier body possesses a lesser KE.
3. A roller is pushed by applying a force of 50 N. The line of action of the force makes an angle of 60 with the horizontal. Find the work done in moving it through a distance of 10 m.
   (Ans. 250 J)
4. Calculate the momentum of a body of mass 100 g having kinetic energy of 20 joule. (Ans. 2 kg-m/s)
5. Calculate the amount of work done taking a packet of mass 100 kg to the top of a building of height 14.0 m. Take $g = 10$ m/s^2.
   (Ans. 1.4×10^4 J)
6. The momentum of a body increases by 20%. Calculate the percentage increase in its KE. (Ans. 44)
7. The momentum of a body decreases by 20%. Calculate the percentage decrease in its KE. (Ans. 36)
8. A bullet leaves a rifle with a velocity of 200 m/s and stikes a wooden target up to 4 cm. What velocity should it have to pierce the same block of wood up to 16 cm ? (Ans. 400 m/s)
9. The mass of a pendulum bob is 100 g, and the string is 1 m long. The bob is held so that the string horizontal. It is then allowed to fall. Find the KE when the string makes an angle of (a) 0° (b) 30° with the vertical.
   (Ans. (a) 98×10^5 erg; (b) 84×10^4 erg)

10. What horsepower is necessary to lift 180 tonnes of coal per hour, from a mine 120 m deep ? (Ans. 78.82)

11. An elevator lifts a load of 1250 kg through a height of 20 m in 5 s. Calculate the power of the elevator. (Ans. 49 kW)

12. A bullet of mass 5 g leaves a rifle with a velocityof 2 m/s. If it strikes a wooden target and penetrates 20 cm into it, what is the average resistance offered by th target? (Ans. 5000 dynes)

13. The human heart forces 4500 cc of blood per min. through the arteries, under a pressure of 15 cm of Hg. Calculate the hp of the heart. Take 1 hp = 746 W and g = 980 cm/s.
(Ans. 20×10^{-4} approx.)

14. A pump is required to lift 480 kg of water per min. from a well 10 m deep, and eject it with a speed of 10 m/s.

    (a) How much work is done in lifting the water ?

    (b) What is the magnitude of the KE given to water ?

    (c) What is the horse power of the engine ?

    (Ans. (a) 47,040 J (b) 24,000 J, and (c) 1.6)

15. A boy of mass 50 kg sits on a swing, suspended by a rope 5 m long. A person pulls the rope that makes an angle of 30° with the vertical. What is the gain in the gravitational potential energy of the boy? (Ans. 328.3 J)

16. A ball is dropped from rest from a height of 12 m. If the ball loses 25% of its KE on striking the ground, what is the height to which it bounces? How do you account for the loss in KE.
(Ans. 9 m)

17. A car of mass 1000 kg travels at 12 m/s on a horizontal and the resistance to motion is 500 N. Find (a) its momentum (b) its kinetic energy and (c) the power developed by the engine.
(Ans. (a) 1.2×10^4 N–S, (b) 7.2×10^4 J, and (c) 6.0 kW)

18. The brakes of an unloaded lorry of mass 1000 kg will slow it down from 40 to 20 km/h in 7.5 s. How long will they take to stop it from a speed of 30 km/h, if it has taken on a load of 2200 kg ? (Ans. 36 s)

19. If the frictional force resisting the motion of a car is 300 N, find the work done (i.e, the energy expended) by a man who pushes the car at a steady rate for 25 m on a horizontal road.
(Ans. 7500 J)

20. The propelling force of a rocket increases uniformly from zero to 5 N in the first 12 m and remains constant for the next 40 m. Find the total work done. (Ans. 2300 J)

21. The potential energy stored in the wound-up spring of a toy motor-car is 18 J. Ignoring any frictional resistance to motion, find the distance this car (mass 200 g) will travel up a slope of 1 in 5. (Ans. 45.9 cm)

22. A body of mass 20 kg falls through a distance of 50 cm. What is the loss in PE ? (Ans 98 J)

OBJECTIVE EVALUATION

1. Work done upon a body is
   (a) a vector quantity (c) always positive
   (b) a scalar quantity (d) always negative

2. In the SI system, the unit of PE is
   (a) erg (c) N-m
   (b) dyne-cm (d) none of these

3. Kilowatt hour (kWh) represents the unit of
   (a) power (c) momentum
   (b) impulse (d) none of these

4. Two unequal masses possess the same KE. Then, the heavier mass has
   (a) greater momentum
   (b) smaller momentum
   (c) the same momentum as the lighter mass
   (d) greater speed

5. Two unequal masses possess the same momentum, then the kinetic energy of the heavier mass is ____________ the kinetic energy of the lighter mass.
   (a) same as (c) smaller than
   (b) greater than (d) much greater than

6. The speed of a motor car increase six times, then the kinetic energy increases
   (a) 6 times (c) 12 times
   (b) 36 times (d) 24 times

7. The number of joules contained in 1 kWh is

(a) 36×10^3 (c) 36×10^4

(b) 36×10^3 (d) 3.6×10^6

8. A body is moves through a distance of 3 m/in the following different ways. In which case is the maximum work done ?
   (a) When pushed over an inclined plane
   (b) When lifted vertically upward
   (c) When pushed over smooth rollers
   (d) When pushed on a plane, horizontal surface
9. In the above example, the work done is minimum when the body is
   (a) pushed over an inclined plane
   (b) lifted vertically upward
   (c) pushed over the smooth rollers
   (d) pushed on a plane horizontal surface
10. A truck and a car are moving on a smooth, level road such that the KE associated with them is the same. Brakes are applied to both of them simultaneously. Which one will cover a greater distance before it stops?
    (a) Car (c) Both will cover the same distance
    (b) Truck (d) Nothing can be decided
11. A wound watch spring has ________________ energy.
    (a) mechanical (c) potential
    (b) kinetic (d) kinetic & potential
12. Two bullets P and Q, of mass 10 and 20 g, are moving in the same direction towards a target with velocities of 20 and 10 m/s respectively. Which one of the bullets will pierce a greater distance through the target ?
    (a) P (c) both will cover the same distance
    (b) Q (d) nothing can be decided
13. When the time taken to complete a given amount of work increases, then,
    (a) power increases (c) energy increases
    (b) power decreases (d) energy decreases

14. When the force applied, and the displacement of the body are inclined at 90° with each other, the work done is

    (a) infinite (c) zero

    (b) maximum (d) unity

15. A car moving along a straight level road with constant speed. Then

    (a) the work done on the car, infinite

    (b) the work done on the car is zero

    (c) the work done on the car is a measure of the gravitational potential energy

    (d) the work done on the car cannot be found.

16. $Kg/m^2/s^2$ represents the unit of

    (a) kinetic energy (c) potential energy

    (b) work done (d) all the above

17. The moon revolves around the earth because the earth exerts a radial force on the moon. Does the earth perform work on the moon ?

    (a) No (c) Yes, always

    (b) Yes, sometimes (d) Cannot be decided

18. The KE of a body is increased most, by doubling its

    (a) mass (c) speed

    (b) weight (d) density

19. A body is dropped from a certain height from the ground. When it is halfway down, it possesses,

    (a) only KE (c) only PE

    (b) both KE and PE (d) zero energy

20. A body of mass 20 kg is dropped from a height of 2 m. If g is taken to be equal to 10 m/s^2, the kinetic energy of the body, just before striking the ground, will be

    (a) 400 Joules (c) 40 Joules

    (b) 4 Joules (d) none of these

21. The energy required to raise a given volume of water from a well can be

    (a) megawatts (c) megajoules

    (b) meganewton (d) kilowatts

22. Two spherical balls of the same radius, but of different masses,

are dropped at the same time from the top of a tower 19.6 m high. When they are 1.6 m above the ground, the balls will possess the same

(a) KE (c) momentum

(b) PE (d) total energy

23. Asha lifts a doll from the floor and places it on a table. If the weight of the doll is known, what else does one need to know in order to calculate the work Asha has done on the doll ?

(a) The time required (c) Mass of the ball

(b) Height of the table (d) Cost of the doll or the table

24. One kilowatt is approximately equal to

(a) 1.30 hp (c) 2.50 hp

(b) 1.56 hp (d) 1.83 hp

25. The work done in lifting a mass of 1 kg to a height of 9.8 m is

(a) 1 J (c) 9.8 J

(b) $(9.8)^2$ J (d) none of these

26. Two bodies of equal weight are kept at heights of h and 1.5 h respectively. The ratio of their PE is

(a) 3 : 2 (c) 1 : 1

(b) 2 : 3 (d) none of these

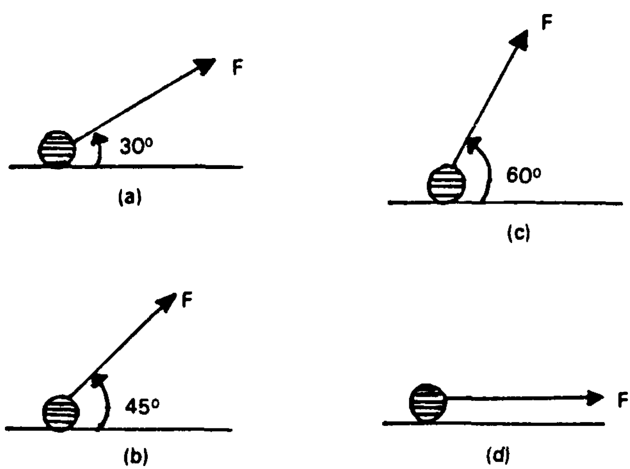


Fig. 6.7

27. In which of the following cases will the work done be maximum ? The body is moved through a distance S on the ground.

(a) A (c) C

(b) B (d) D

28. One of the rectangular components of a force of 50 N is 30 N. The other rectangular component will be

(a) 40 N (c) 35 N

(b) 30 N (d) 45 N

29. The work done by a centripetal force

(a) increases by decreasing the radius of the circle

(b) decreases by increasing the radius of the circle

(c) increases by increasing the mass of the body

(d) is always zero

30. The units N-S are equivalent to

(a) J (c) kg-m-s^{-2}

(b) kg-m-s^{-1} (d) N-m-s

31. Certain weight is attached with a spring. It is pulled down and then released. It oscillates up and down. Its KE will be

(a) maximum in the middle of the movement

(b) maximum at the bottom

(c) maximum just before it is released

(d) constant

32. A photocell converts light energy into

(a) chemical energy (c) heat energy

(b) electrical energy (d) mechanical energy

33. Escape velocity depends upon

(a) mass of the body (c) radius of the earth

(b) shape of the body (d) none of these

34. Mathematically escape velocity is given as

(a) $v = \sqrt{2R_e g}$ (c) $v = \sqrt{\frac{2R_e}{g}}$

(b) $v = \frac{1}{\sqrt{2R_e g}}$ (d) $v = \sqrt{\frac{2g}{R_e}}$

35. A rocket with a velocity greater than ______________ will escape into space.

(a) 11.16 km/s
(b) 11.16 m/h
(c) 11.16 m/min
(d) 11.16 km/min

36. A flying aeroplane has
(a) only potential energy
(b) only kinetic energy
(c) both potential and kinetic energy
(d) none of these

37. A steam engine converts
(a) heat energy into sound energy
(b) heat energy into mechanical energy
(c) mechanical energy into heat energy
(d) electrical energy into sound energy

38. A truck and a car are moving on a smooth level road such that the KE associated with them is the same. Which one will cover greater distance when brakes are applied to them simultaneously ?
(a) car
(b) truck
(c) both will cover the same distance
(d) none of these

39. Mechanically work done is equal to
(a) $W = F/d$
(b) $W = Fd$
(c) $W = F + d$
(d) $W = F - d$

40. A body at rest can have
(a) speed
(b) energy
(c) momentum
(d) velocity

True or False Statements

1. A loud speaker changes sound energy into electrical energy
2. When energy changes from one form to another, the energy that disappears from one form, reappears in exactly equivalent amount in the other form.
3. A force does not work, if it produces no motion.
4. Kilowatt hour is the unit of power.

5. Escape velocity depends only on the mass and radius of the earth.
6. In order to get minimum work, the angle between force and displacement should be 90°.
7. Work is a vector quantity.
8. When a body falls on the ground and stops, the principle of conservation of energy is violated.
9. When velocity is halved, its kinetic energy becomes 1/4th.
10. When an arrow is released from a bow, potential energy changes into kinetic energy.
11. Mass is also a form of energy.
12. 1 erg $=$ 10^7 Joule.
13. Work done by a force depends upon how fast work is done.
14. The rate of doing work is called power.
15. Work done by a centripetal force is zero.
16. The unit of work is watt.
17. The escape velocity from the moon is six times smaller than that from the earth.
18. If we know the speed and mass of an object we can find out its kinetic energy.
19. 1 Kwh $= 3.6 \times 10^6$ Joule.
20. Energy stored in the spring of a watch is kinetic energy.

ANSWERS (OBJECTIVE EVALUATION)

1. (b)	2. (d)	3. (d)	4. (a)	5. (c)	6. (b)	7. (d)	8. (b)	9. (c)
10. (c)	11. (c)	12. (a)	13. (b)	14. (c)	15. (b)	16. (d)	17. (a)	18. (c)
19. (b)	20. (a)	21. (c)	22. (d)	23. (b)	24. (a)	25. (b)	26. (b)	27. (d)
28. (a)	29. (d)	30. (b)	31. (a)	32. (b)	33. (c)	34. (a)	35. (a)	36. (c)
37. (b)	38. (c)	39. (b)	40 (b)					

ANSWERS (TRUE / FALSE)

1. (F)	2. (T)	3. (T)	4. (F)	5. (F)	6. (T)	7. (F)	8. (F)	9. (T)
10. (T)	11. (T)	12. (F)	13. (F)	14. (T)	15. (T)	16. (F)	17. (F)	18. (T)
19. (T)	20. (F)							

UNIT SEVEN
HEAT

REVIEW CONCEPTS

Heat is a kind of energy that gives us the sensation of hotness or coldness.

Calorie is a unit of heat. One calorie is the amount of heat required to raise the temperature of 1 g of water through 1°C.

One kilocalorie is the amount of heat required to raise the temperature of 1 kg of water through 1°C.

Temperature is the degree of hotness or coldness. It can be measured in °C or °F or K.

Thermometer is a device to measure temperature.

Thermal equilibrium : When two bodies, A and B are brought in thermal contact and there is no transfer of heat from A to B and B to A, they are said to be in thermal equilibrium.

Fahrenheit scale : On this scale the lower fixed point is 32°F and the upper fixed point is 212°F. It was given by a scientist by the name of Fahrenheit.

Celsius scale : The lower fixed point on this scale is 0° C and the upper fixed point is 100°C.

Thermometric substance is that substance whose property is utilised for measuring temperature.

Principle of liquid thermometer : Liquids expand on heating and their expansion is generally regular and uniform.

Specific heat : The quantity of heat required to raise the temperature of 1 kg of a substance through 1°C. It is denoted by 'C.' Its SI unit is J/kg/°C.

Thermal capacity is the amount of heat required to raise the temperature of a body through 1°C. Unit is J/°C.

Solid : The intermolecular forces are very strong. Energy of molecules is less.

Liquids : The intermolecular forces are small. Energy of molecules is large.

Gases : The intermolecular force is least. Energy of molecules is very large.

Flow of heat takes place from a body at a higher temperature to a body at a lower temperature, when placed in thermal contact.

Dependence of specific heat : Specific heat depends upon the material of the body.

Heat absorbed or evolved depends upon the mass and the change in temperature.

Expansion of all materials takes place on heating due to the increase in the intermolecular distance.

Linear expansion : When increase in length, breadth or thickness is considered, such an expansion is called linear expansion.

Coefficient of linear expansion is the increase in length per unit length per degree rise in temperature. Its unit is l °C and is denoted by α.

Coefficient of cubical (volumetric) expansion is the increase in volume per degree rise in temperature. It is denoted by γ.

Change of state : Change of solid to liquid or liquid to gas and vice-versa without change in temperature is called change of state.

Latent heat is the hidden heat in the system. It is defined as the quantity of heat required to change its state without any change in its temperature. Its units are cal/g or J/kg or kcal/kg.

Latent heat of fusion of ice is the quantity of heat required to raise the temperature of 1 kg of ice at 0°C completely to 1 kg of water at the same temperature. Its value is 80 Kcal/1 kg or 3.36×10^5 J/kg.

Latent heat of steam is the quantity of heat required to raise the temperature of 1 kg of water at 100°C to steam at 100°C. Its value is 540 Kcal/kg or 2.27×10^6 J/kg.

Latent heat of solidification is the amount of heat given out by 1 kg of a liquid to fuse into solid state at its freezing point.

Relative humidity is the ratio of amount of water vapour actually present in a given volume of air at a certain temperature to the amount of water vapour required to saturate the same volume of air at the same temperature.

Mechanical equivalent of heat is the ratio of mechanical work to the heat produced. It is denoted by J.

Equilibrium temperature is that temperature attained by two bodies when they are brought in thermal contact with each other and a state of thermal equilibrium is attained.

Formulae

1. Relation between °C, °F and K

$$\frac{C-0}{100-0}=\frac{F-32}{212-32}=\frac{K-273}{373-273}$$

$$\text{In general} = \frac{\text{Temp. of any scale} - \text{lower fixed point}}{\text{Upper fixed point} - \text{lower fixed point}}$$

where C, F and K represent the readings on the Celsius, Fahrenheit and absolute scales respectively.

A change of 100°on the centigrade scale

= a change of 180° on the Fahrenheit scale

= a change of 100° on the kelvin scale.

$°F = 1.8\,(°C + 32)$

$°C = 0.556\,(°F - 32)$

Heat gain $Q = mCT$ or $Q = mC(T_2 - T_1)$

where Q = heat gain

m = mass

C = specific heat and

T = change in temperature

Heat lost = Heat gained

Change in length $\Delta l = l_2 - l_1 = l\,\alpha\,\Delta T$

where l_2 = final length

l_1 = initial length

α = coefficient of linear expansion and

T = change in temperature

$$\text{Coefficient of linear expansion } \alpha = \frac{l_2 - l_1}{l_1 \times (T_2 - T_1)}$$

where symbols have got their usual meaning

$$\text{Coefficient of volumetric expansion } \gamma = \frac{V_2 - V_1}{V_1 \times (T_2 - T_1)}$$

where V_2 = final volume

V_1 = initial volume

T_2 = final temperature and

T_1 = initial temperature

Relation between α and γ

$$\alpha = \frac{\gamma}{3} \quad \text{or} \quad \gamma = 3\alpha$$

Thermal capacity $= m \times c$

In case of latent heat $Q = mL$
where L = latent heat
Relative humidity

$$RH = \frac{m}{m_s} \times 100\%$$

where m = mass of water vapours actually present and
m_s = mass of water vapour required to saturate the same volume of air.

NUMERICAL PROBLEMS (SOLVED)

EXAMPLE 1 If we take 15 g of water and add 60 calories of heat to it, what is the rise in its temperature ?

Solution: Given,

Mass of water (m) = 15 g
Heat added (Q) = 60 calories
Sp. heat of water (C) = 1 cal/g °C

To calculate : Change in temperature (ΔT) = ?

Formula to be used : $Q = mC\Delta T$

or

$$\Delta T = \frac{Q}{mC}$$

Substitute the given values

$$\Delta T = \frac{60}{15 \times 1}$$

$$\Delta T = 4°C$$

EXAMPLE 2 How much heat must be added to raise the temperature of 100 g of water from 5°C to 95°C ?

Solution: Given,

Mass of water (m) = 100 g
Initial temperature (T_1) = 5°C
Final temperature (T_2) = 95°C
Sp. heat of water (C) = 1 cal/g °C

To calculate : Heat required (Q) = ?

Formula to be used : $Q = mC(T_2 - T_1)$

Substituting the given values, we get

$$Q = 100 \times 1 \times (95 - 5)$$
$$= 100 \times 1 \times 90 = 9000 \text{ cal}$$

EXAMPLE 3 How much heat is required to raise the temperature of 150 g of iron from 20°C to 25°C ? (Given C = 0.11 cal/g °C)

Solution: Given,

Mass of iron $(m) = 150$ g
Initial temperature $(T_1) = 20$°C
Final temperature $(T_2) = 25$°C
Sp. heat of iron (C) = 0.11 cal/g°C

To calculate : Amount of heat (Q) = ?

Formula to be used : $Q = mC(T_2 - T_1)$

Substituting the given values,

$$Q = 150 \times 0.11 \times (25 - 20)$$
$$= 150 \times 0.11 \times 5 = 82.5 \text{ cal}$$

EXAMPLE 4 At 40°C, 51 g of water vapour saturates 1 cubic metre of air. Now if at 40°C there are 25.5 g of water vapour present in 1 cubic metre of air, then find out the relative humidity.

Solution: Given,

Mass of water vapour present $(m) = 25.5$ g
Mass of water vapour to be saturate $(m_s) = 51$ g

To calculate : Relative humidity (RH) = ?

Formula to be used : $\text{RH} = \frac{m}{m_s} \times 100\%$

$$\text{RH} = \frac{25.5}{51} \times 100$$
$$\text{RH} = 50\%$$

EXAMPLE 5 At what temperature will the centigrade scale and Fahrenheit scale indicate the same reading ?

Solution: Let x be the temperature at which the centigrade scale and Fahrenheit scale give the same reading.

Formula to be used : °C = 0.556 (°F − 32)

where °C = temperature in °C
°F = temperature in °F

Since in this case both scales are to measure (read) the same temperature

$$x = 0.556\,(x - 32)$$

or $$x = 0.556\,x - 0.556 \times 32$$

$$= (x - 0.556\,x) = -0.556 \times 32$$

$$0.444\,x = -17.792$$

or $$x = -40^{\circ}C \quad \text{or} \quad x = -40^{\circ}F$$

$$-40^{\circ}C = -40^{\circ}F$$

At -40° both the scales will give the same reading.

EXAMPLE 6 What is the normal temperature of a human body on the Kelvin scale ?

Solution: Given,

Normal temperature of a human body in °F = 98.6°F

To calculate : Temperature of a normal human body in (K) = ?

Formula to be used : $$\frac{F - 32}{180} = \frac{K - 273}{100}$$

Substituting F = 98.6, we will find out K

$$\frac{98.6 - 32}{180} = \frac{K - 273}{100}$$

$$\left[\frac{(98.6 - 32) \times 100}{180}\right] + 273 = K$$

$$\left[\frac{66.6 \times 100}{180}\right] + 273 = K$$

$$310 = K$$

EXAMPLE 7 At what temperature will the reading on the Fahrenheit scale be double than that on the Celsius scale ?

Solution: Let x be the temperature on the Fahrenheit scale

Temperature on celsius scale = $2\,x$

Formula to be used : $^{\circ}C = 0.556(^{\circ}F - 32)$

Putting $^{\circ}C = 2\,x$ and $^{\circ}F = x$, we get

$$2\,x = 0.556\,(x - 32)$$

$$= (2\,x - 0.556x) = -0.556 \times 32$$

$$1.444\,x = -17.792$$

$x = -12.3°F$

$2x = -24.6°C$

Temperature on F-scale = – 12.3° and

Temperature on C-scale = – 24.6°

EXAMPLE 8 At what temperature will the reading on the Celsius scale be double than that on the Fahrenheit scale ?

Solution: Let x be the temperature on the celsius scale which gives double the temperature on the Fahrenheit scale.

Temperature on F-scale = $2x$°F

Formula to be used : °C = 0.556(°F – 32)

Putting °C = x and °F = $2x$, we get

$$x = 0.556(2x - 32)$$

$$[x - (0.556 \times 2x)] = -32 \times 0.556$$

$$(x - 1.112x) = -17.792$$

=> $x = 160°C$ or $2x = 320°F$

EXAMPLE 9 How much heat is needed to raise the temperature of 10 kg of lead from 20° C to 120° C. The sp. heat of lead is 0.03 Kcal/kg °C.

Solution: Given,

Mass (m) = 10 kg

Initial temperature (T_1) = 20°C

Final temperature(T_2) = 120°C

Sp. heat of lead (C) = 0.03 Kcal/kg°C

To calculate : Heat required (Q) = ?

Formula to be used : $Q = mc(T_2 - T_1)$

$$Q = 10 \times 0.03 \times (120 - 20)$$

$$= 10 \times 0.03 \times 100$$

$$= 30 \text{ Kcal}$$

EXAMPLE 10 Find the amount of heat in joules given out by a piece of iron of mass 100 g when it cools from 100°C to 30°C. Specific heat of iron is 460 J/kg °C.

Solution: Given,

Mass (m) = 100 g = 100×10^{-3} kg

Initial temperature (T_1) = 100°C

Final temperature (T_2) = 30°C

Sp. heat (C) = 460 J/kg °C

To calculate : $Q = ?$

Formula to be used : $Q = mc\,(T_2 - T_1)$

$$Q = 100 \times 10^{-3} \times 460\,(30 - 100)$$
$$= 100 \times 10^{-3} \times 460\,(-70)$$
$$= -3220\text{ J}$$

Negative sign here indicates that heat is given out by the iron piece.

EXAMPLE 11 10 kg of hot water in a bucket at 70° C is cooled for taking bath by mixing 20 kg of water at 10°C. What is the temperature of the mixture ? (Neglect thermal capacity of the bucket.)

Solution: Given,

Mass of hot water (m_h) = 10 kg

Sp. heat of hot water (C_1) = C

Temperature of hot water (T_h) = 70°C

Mass of cold water (m_c) = 20 kg

Sp. heat of cold water (C_2) = C

Temperature of cold water ($T_{\cdot C}$) = 10°C

To calculate : Temperature of the mixture (final temp.) (T_f) = ?

Formula to be used : Heat lost = Heat gain

$$Q_h = Q_c$$

Here, heat is lost by hot water and gained by cold water.

Heat lost by hot water (Q_h) = $m_h \times C \times (T_h - T_f)$ and

Heat gained by cold water (Q_c) = $m_c \times C \times (T_f - T_c)$

$$Q_h = Q_c$$
$$m_h \times C \times (T_h - T_f) = m_c \times C \times (T_f - T_c)$$
$$10 \times C \times (70 - T_f) = 20 \times C \times (T_f - 10)$$
$$= 30T_f = 900$$
$$T_f = 30°\text{C}$$

EXAMPLE 12 The coefficient of linear expansion of copper is $16 \times 10^{-6}/^{\circ}C$. Calculate the increase in length of a copper wire 5.0 m long when it is heated through 2° C.

Solution: Given,

Coefficient of linear expansion (α) = $16 \times 10^{-6}/^{\circ}C$

Original length (l_1) = 5.0 m

Change in temp. (ΔT) = 2°C

To calculate : Increase in length (Δl) = $l_2 - l_1$ = ?

Formula to be used : $(l_2 - l_1) = \alpha \times l_1 \Delta T$

Substituting the given values

$$(l_2 - l_1) = 16 \times 10^{-6} \alpha 5 \times 2$$

$$\Delta l = l_2 - l_1 = 16 \times 10^{-5} \text{ cm}$$

EXAMPLE 13 Boiling point of water is 100° C. Express this in SI units.

Solution: Temperature in(°C) = 100 °C

To calculate : Temperature in K = ?

Formula to be used : $\frac{C}{100} = \frac{K - 273}{100}$

$$\frac{100}{100} = \frac{K - 273}{100}$$

$$1 \times 100 = K - 273$$

$$= 100 + 273 = K \text{ or } K = 373$$

EXAMPLE 14 If the coefficient of cubical expansion of a material is 5.4×10^{-5} per Kelvin, what is its coefficient of linear expansion ?

Solution: Given,

Coefficient of cubical expansion (γ) = $5.4 \times 10^{-5}/K$

To calculate : Coefficient of linear expansion α = ?

Formula to be used : $\alpha = \frac{\gamma}{3}$

$$\therefore \quad \alpha = \frac{5.4 \times 10^{-5}}{3}$$

$$\alpha = 1.8 \times 10^{-5}/K$$

EXAMPLE 15 A railway line 1200 km long is laid at 25°C. By how much will it contract in winter when the temperature falls to 15°C ? By how much will it expand when the temperature rises to 40°C in summer ? (Given, coefficient of linear expansion = 12×10^{-6} /°C.)

Solution: Given,

Original length (l_1) = 1200 km

= 1200×10^3 m

Final temperature during winter (T_w) = 15°C

Initial temperature (T) = 25°C

Final temperature during summer (T_s) = 40°C

Coefficient of linear expansion(α) = 12×10^{-6}/°C

To calculate : Change in length (Δl) = ?

Formula to be used : $\Delta l = l_1\alpha (\Delta T)$

Case I Contraction during winter

$$\Delta l = 1200 \times 10^{-3} \times 12 \times 10^{-6} \times (15 - 25)$$

$$= 1200 \times 10^{-3} \times 12 \times 10^{-6} \times (-10)$$

$$= -1200 \times 10^{3} \times 12 \times 10^{-6} \times 10$$

$\Delta l = -144$ m (Negative sign indicates contraction)

Case II During summer when it will expand.

$$\Delta l = l_1 \alpha \Delta T$$

$$= 1200 \times 10^3 \times 12 \times 10^{-6} (40 - 25)$$

$$= 1200 \times 10^3 \alpha 12 \times 10^{-6} \times 15$$

$$\Delta l = 216 \text{ m}$$

EXAMPLE 16 What space must be left between two railway lines 25 m long, laid at 25°C to allow the expansion up to 50°C. Coefficient of linear expansion of the material of the track is 1.5×10^{-5}/°C.

Solution: Given,

Original length (l_1) = 25 m

Initial temperature (t_1) = 25°C

Final temperature (t_2) = 50°C

Coefficient of linear expansion (α) = 1.5×10^{-5}/°C

To calculate : Change in length (Δl) = $l_2 - l_1$

Formula to be used : $l_2 - l_1 = l_1 \times \alpha \times \Delta t$

Substituting the given values,

$$l_2 - l_1 = 25 \times 1.5 \times 10^{-5} \times 25$$
$$= 625 \times 1.5 \times 10^{-5}$$
$$\Delta l = 937.5 \times 10^{-5} \text{ m}$$

EXAMPLE 17 The volume of a brass ball is 800 cc at 20° C. Find out the new volume of the ball if the temperature is raised to 52° C. Given the coefficient of volumetric expansion of brass is 48×10^{-6}/°C.

Solution: Given

Initial volume (v_1) = 800 cc

Initial temperature (t_1) = 20°C

Final temperature (t_2) = 52°C

Coefficient of volumetric expansion

(γ) = 48×10^{-6}/°C

To calculate : Final volume (v_2) = ?

Formula to be used : $v_2 = v_1 [1 + \gamma (t_2 - t_1)]$

$$\therefore \quad v_2 = 800 [1 + 48 \times 10^{-6} (520 - 20)]$$
$$= 800 [1 + 48 \times 10^{-6} (500)]$$
$$= 800 [(1 + 240 \times 10^{-4})]$$
$$= 800 + 800 \times 240 \times 10^{-4}$$
$$= 800 + 19.2$$
$$v_2 = 819.2 \text{ cm}^3$$

EXAMPLE 18 An iron ball weighing 1.5 kg absorbs 800 calories of heat to raise its temperature from 30° C to 50° C. Determine the thermal capacity and the specific heat of the iron ball.

Solution: Given,

Mass of the iron ball (m) = 1.5 kg = 1.5×10^3 g

Heat absorbed (Q) = 800 calories

Initial temperature (t_1) = 30°C

Final temperature (t_2) = 50°C

To calculate : Specific heat (C) = ?

Thermal capacity = ?

Formula to be used : (i) $Q = MC(t_2 - t_1)$

$$C = \frac{Q}{m\,(t_2 - t_1)}$$

(ii) Thermal capacity $= m \times C$

To find C

$$C = \frac{Q}{m\,(t_2 - t_1)} = \frac{800}{1.5 \times 10^3\,(50 - 30)}$$

$= 0.027$ cal/g °C

Now, thermal capacity $= mC$

$= 1.5 \times 10^3 \times 0.27$

$= 40.5$ cal/ °C.

EXAMPLE 19 200 g of hot copper is dropped on a block of ice at 0°C. As a result 200 g of ice melts. What was the temperature of copper when it was dropped (C of the copper = 400 J/kg, Latent heat of fusion of ice = 336000 J/kg)?

Solution: Given,

Mass of copper (m_1) = 200 g = 0.2 kg

Initial temperature of ice (t_1) = 0°C

Amount of ice melt (m_2) = 200 g = 0.2 kg

Specific heat of copper (C) = 400 J/kg

Let temperature of the copper (t_2) = θ

Latent heat of fusion of ice (L) = 336000 J/kg

To calculate : Initial temperature of copper (t_2) = θ

Formula to be used : (i) Heat lost = Heat gained

(ii) Heat gained by ice in melting = mL

(i) Heat lost by copper

$= m \times C \times (t_2 - t_1)$

$= 0.2 \times 400 \times (\theta - 0)$

$= 0.2 \times 400 \times \theta$

Heat lost = $80\,\theta$ J

(ii) Heat gained by ice in melting

$mL = 0.2 \times 336000 = 67200$ J

Heat lost = Heat gained

$$80\,\theta = 67200$$

$$\theta = \frac{67200}{80} = 840^\circ C$$

EXAMPLE 20 Calculate the amount of heat required to completely change 5.0 g of ice at – 10° C into steam. (Specific heat of ice = 2100 J/kg), Latent heat of fusion of ice = 336 KJ/kg, Specific heat of water = 4200 J/kg and Latent heat of steam = 226 MJ/kg).

Solution: Given,

Mass of ice (m) = 5.0 g = 5×10^{-3} kg

Initial temperature (t_1) = – 10°C

Final temperature of ice (t_2) = 0°C

Temperature of steam (t_3) = 100°C

To calculate : Heat required (Q) = ?

Formula to be used : (i) $Q = mC\,(t_2 - t_1)$

(ii) $Q = mL$

Now in this case, first heat is required to

(i) change ice from – 10°C to 0°C (mCT)

(ii) to melt ice without changing the temperature (mL)

(iii) raise the temperature of water (formed from ice) from 0°C to 100°C (mCT)

(iv) change water at 100°C to steam at 100°C(mL)

(i) First case

$$Q_1 = m \times C \times T$$

$$= 0.005 \times 2100 \times 10 = 105\text{ J}$$

(ii) Second case

$$Q_2 = mL$$

$$= 0.005 \times 336000 = 1680\text{ J}$$

(iii) Third case

$$Q_3 = m \times C \times T$$

$$= 0.005 \times 4200 \times 100 = 2100\text{ J}$$

(iv) Fourth case

$$Q_4 = mL$$

$$= 0.005 \times 2260000 = 11300\,\text{J}$$

$$\text{Total heat } Q = Q_1 + Q_2 + Q_3 + Q_4 = 15185\,\text{J}$$

NUMERICAL PROBLEMS (UNSOLVED)

1. Calculate the quantity of heat required to raised the temp. of 1 kg of water from 30°to 70°C. (Ans. 4×10^4 cal)
2. Calculate the quantity ofheat required to raise the temperature of200 g of a liquid (Specific heat = 0.8 cal/g/°C) from 10°to 60° C. (Ans. 8×10^3 cal)
3. Calculate the amount of heat required to raise the temperature of 10 g of water from 0°to 98°C. (Ans. 98 Kcal)
4. Find the rise in temperature of 10 kg of water at 5°C, when 10^5 cal of the heat is given to it. Take the specific heat of water as 1 cal/g/°C. What will be the final temperature ? (Ans. 10°C, 15°C)
5. Calculate the amount of heat required to raise the temp, of 10 g of ice at 0°C into water at 50°C. (Ans. 1300 cal)
6. Calculate the amount of heat required to raise the temperature of 10 g of ice at – 20°C into water at 20° C. (Ans. 1100 cal)
7. A kilogram of ice at – 10°C is heated till the whole of it evaporates. How much heat is required ? Specific heat of ice is 0.5 cal/g/°C, latent heat of water is 80 cal/g and that of steam is 540 cal/g. (Ans. 725×10^2 cal)
8. When a piece of metal weighing 48.3 g at 10.7° C was immersed in a current of steam at 100°C, 0.762 g of steam was found to condense. Calculate the specific heat of the metal. (Ans. 0.095 cal/g/°C)
9. Copper nails, weighing 100 g and heated to 100° C, are dropped into a calorimeter of mass 100 g containing 40 g of a mixture of ice and water. If the resulting temperature is 10° C, find out how much ice is present. Specific heat of copper = 0.09 cal/g/°C. (Ans. 4 g)
10. Find the result of mixing equal masses of ice at – 10° C and water at 60°C. Specific heat of ice is 0.5 cal/g/°C. (Ans. Temperature is 0°C, and 11/16 of total mass of ice melts)

11. Compare the amounts of heat needed to raise a mass of water from 0°to 100°C, with that required to convert the same mass of ice into steam. Take latent heat of fusion of ice as 80 cal/g and latent heat of steam as 536 cal/g. (Ans. 1 : 7.16)

12. Find the amount of heat required to boil off 20 g of ice at – 10°C. Latent heat of steam = 540 cal/g and specific heat of ice = 0.5 cal/g/°C. (Ans. 14500 cal)

13. Equal volumes of mercury and glass have the same thermal capacity. Calculate the specific heat of a piece of glass of specific gravity 2.5, if the specific heat of mercury is 0.0333 cal/°C and its specific gravity is 13.6. (Ans. 0.181 cal/g/°C)

14. A liquid of specific heat 0.5 at 60°C, is mixed with another liquid of specific heat 0.3 at 20°C. After mixing, the temperature of the mixture becomes 30°C. In what proportion by weight, are the liquids mixed? (Ans. 1 : 5)

15. Three liquids A, B and C are given. A mixture of 4 g of A at 60°C and 1 g of C at 50°C, after mixing, attains a temperature of 55°C. A mixture of 1 g of A at 60°C and 1 g of B at 50°C shows a temperature of 55°C. What would be the temperature of a mixture of 1 g of B at 60°C and 1 g of C at 50°C ? (Ans. 52°C)

16. It takes 15 minutes for an electric kettle to heat a certain quantity of water from 0°C to the boiling point, 100° C. It requires 80 minutes to turn all the water at 100°C into steam. Determine the latent heat of steam. (Ans. 533.3 cal/g)

17. The latent heat of liquid ammonia is 340 cal/g. Calculate the quantity of liquid ammonia required to manufacture ice weighing 100 g, when the temperature of water is 50° C and latent heat of ice is 80 cal/g. (Ans. 25 g)

18. Latent heat of ether at 0°C is 90 cal/g. How much ether should be evaporated to freeze 60 g of water at 0° C? (Ans. 53.33 g)

19. As much as 100 g of platinum, after heating up to 1000° C, is put in ice. Find the specific heat of platinum if 40 g of ice melts. Latent heat of ice = 80 cal/g. (Ans. 0.032 cal/g/° C)

20. Half a gram of petrol was completely burnt in a bomb calorimeter, whose water equivalent was 500 g, and which contained 1500 g of water. The rise in temperature was found to be 2.5°C. Find the calorific value of petrol. (Ans. 10,000 cal/g)

21. A square metal sheet having a side of 15 cm at 0° C is heated to 50°C. What is the new area? Given $\beta = 1.778 \times 10^{-5}$/° C. (Ans. 225.2 cm^2)

22. The volume of a given mass of a gas is 120 cc at 20°C. Calculate the temperature required to increase the volume by 12.3 cc, pressure remaining constant. (Ans. 50°C)

23. Calculate the temperature on the clinical thermometer corresponding to 310.78 K. (Ans. 100°F)

24. The length of a metallic rod is 75 cm at 20° C and 75.24 cm at 100°C. Calculate α for the metal. (Ans. 12×10^{-5}/°C)

25. The density of mercury at 50°C is 13.47 g/cc and 13.6 g/cc at 0°C. Calculate the coefficient of cubical expansion of mercury. (Ans. 0.000182/°C)

26. The normal temperature of the human body is 98.4° F. Express it in Reaumur and absolute scales. (Ans. 22.5°R, 309.9 K)

27. A faulty thermometer has its fixed points marked 5°and 95°C. What is the correct temperature in centigrade when this thermometer reads 59°? (Ans. 60°C)

28. A faulty thermometer has its fixed points marked at 6° and 96°. What is the correct temperature on the Fahrenheit scale when this thermometer reads 86°? (Ans. 192° F)

29. An iron rod has a length of 90 cm at a temperature of 20° C, and 90.1 cm at 80°C. Find the coefficient of linear expansion. (Ans. 0.000012/°C)

30. A sphere of diameter 7 cm and mass 266.5 g floats in a bath of liquid. As the temperature is raised, the sphere just begins to sink as the liquid attains a temperature of 35° C. If the density of the liquid at 0°C is 1.527 g/cm^3, find the coefficient of cubical expansion of the liquid. Neglect the expansion of the sphere. (Ans. 0.00084/°C)

31. A copper disc at 0°C has a diameter of 200 cm, and a hole cut in the centre is 10 cm in diameter. What will be the diameter of the hole at 100°C ? Coefficient of linear expansion of copper is 0.000016/°C. (Ans. 10.016 cm)

32. Density of a substance at 0°C and 20°C are 8.80 and 8.40 g/cc respectively. Calculate the coefficient of cubical expansion of the substance. (Ans. 0.0024/°C)

33. A circular iron tyre has a diameter of 0.75 m at 20°C. Find the increase in diameter when the tyre is made red hot (i.e. 900°C) (Ans. 0.79 cm)

34. The specific latent heat of fusion of lead is 2.1 × 10 J/kg and its melting point is 328°C. How many joules will be needed to melt 7.0 kg of lead at 13°C? (Ans. 4.12 × 10^5 J)

35. What mass of ice can be melted by 100 g of water at 22°C. Latent heat of fusion of ice = 3.3 × 10^5 J/kg. (Ans. 28 g)

OBJECTIVE EVALUATION

1. The units for the coefficient of real expansion is

   (a) cm (c) cm – °C

   (b) cm/° C (d) /°C

2. The units for the coefficient of apparent expansion is

   (a) cm (c) cm – °C

   (b) cm/° C (d) /° C

3. With the increase in temperature, the density of a substance, in general,

   (a) increases

   (b) decreases

   (c) first increase then decreases

   (d) first decrease then increases

4. A graph was plotted taking the temperature in °C along the X-axis and the corresponding temperature in Kelvin along the Y-axis, which of the curves in Fig. 7.1 most correctly represents this behaviour ?

   (a) A (c) C

   (b) B (d) D

5. If a graph is plotted taking the temperature in Fahrenheit along the Y-axis, and the corresponding temperature in Celsius along the X-axis, then the graph will be a straight line,

   (a) having a positive intercept on the Y-axis

   (b) having a positive intercept on the X-axis

   (c) passing through the origin

   (d) having negative intercepts on the X and Y axis

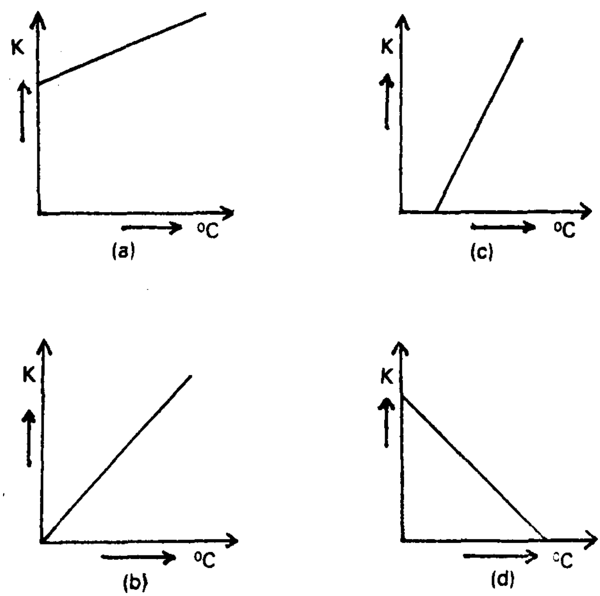


Fig. 7.1

6. The normal temperature of the human body is
   (a) 37°C (c) 36.8°C
   (b) 38°C (d) none of these
7. Two spheres of the same size are made of the same metal, but one is hollow and the other is solid. They are heated to the same temperature :
   (a) the hollow sphere will expand more
   (b) the solid sphere will expand more
   (c) both spheres will expand almost equally
   (d) only the solid sphere will expand
8. Water evaporates under atmospheric pressure. Without changing the temperature, the same water is placed under partial vacuum. The rate of evaporation will
   (a) increase (c) decrease
   (b) drop to zero (d) remain unaffected
9. A mercury thermometer, with a concave reflector behind the

bulb, is placed in front of an electric fire. Which of the following combinations will cause the smallest reading on the thermometer?

(a) Black reflector, black bulb

(b) Black reflector, shiny bulb

(c) Shiny reflector, shiny bulb

(d) Temperature will remain same for any combination.

10. A block of wood is floating on water at 0°C, with a certain volume *V* above water level. The temperature of water is slowly raised from 0°to 20°C. How will the volume *V* change with the rise of temperature ?

(a) *V* will be unchanged

(b) *V* will decrease from 0°C onwards

(c) *V* will decrease till 4°C and then increase

(d) *V* will increase till 4°C and then decrease

11. The unit of the coefficient of linear expansion is

(a) °C

(b) per°C

(c) cm/°C

(d) cm/°C

12. The unit of the coefficient of cubical expansion is

(a) °C

(b) per°C

(c) cm^2 °C

(d) cm^3/°C

13. Coefficient of linear expansion is always ____________ with the increase in temperature.

(a) increases

(b) decreases

(c) remains the same

(d) doubles itself

14. Choose the correct statement :

(a) $\alpha : \beta : \gamma :: 1 : 3 : 2$

(b) $\alpha : \beta : \gamma :: 3 : 2 : 1$

(c) $\alpha : \beta : \gamma :: 2 : 3 : 1$

(d) $\alpha : \beta : \gamma :: 1 : 2 : 3$

15. A thermometer is used to measure

(a) heat

(b) thermal capacity

(c) water equivalent

(d) temperature

16. A graph is plotted taking C along the Y-axis and F along the X-axis. It is a/an

(a) parabola

(b) straight line

(c) ellipse

(d) circle

17. A circular disc of copper has a symmetrical hole at its centre. The disc is uniformly heated. The diameter of the hole will
    (a) increase
    (b) decrease
    (c) remain the same
    (d) become indeterminate

18. When water is heated from 0°C, its volume
    (a) increases
    (b) decreases till 4°C
    (c) remains the same
    (d) first increases then decreases

19. The most commonly used thermometric substance is
    (a) water
    (b) alcohol
    (c) mercury
    (d) none of these

20. In summer, the clocks
    (a) become slow
    (b) become fast
    (c) give correct time
    (d) lose time

21. Therm is the unit of
    (a) heat
    (b) temperature
    (c) thermometry
    (d) work

22. Absolute zero corresponds to
    (a) – 273°A
    (b) 273°C
    (c) 273°R
    (d) none of these

23. If 10 g of ice at 0°C is mixed with 10 g of water at 10°C, then the final temperature t is given by
    (a) $(10 \times 80) + 10(t - 0) = 10(10 - t)$
    (b) $10 \times 80 = 10(10 - t) + 10(t - 0)$
    (c) $t = 5°C$
    (d) $t = 0°C$

24. The temperature of water at the bottom of a large waterfall is higher than that of the water at the top, because
    (a) the falling water absorbs heat from the sun
    (b) the KE of the falling water is converted into heat
    (c) the water at the bottom has greater PE
    (d) rocks on the bed of the river give out heat

25. When salt is properly mixed with ice, the melting point of ice
    (a) is lowered
    (b) is raised
    (c) remains the same
    (d) becomes infinite

26. Steam at 100°C causes more severe burns than water at the same temperature because
    (a) steam is a gas
    (b) steam cannot do work
    (c) steam can provide more heat
    (d) steam is highly combustible
27. When an inflated tyre bursts, the air escaping out
    (a) will get heated up
    (b) will be cooled
    (c) will not undergo any change in its temperature
    (d) will be liquefied
28. A thermos bottle containing coffee is vigorously shaken. If the coffee is considered as a system, then the temperature of the coffee will
    (a) increase slightly
    (b) fall
    (c) remain the same
    (d) never be determined
29. A container containing some gas was kept in a moving train. The temperature of the gas in the container will
    (a) increase slightly
    (b) decrease
    (c) remain the same
    (d) become infinite
30. Two glass tumblers have been stuck together (one into the other). They can be separated by
    (a) placing hot water in the inner tumbler
    (b) placing the tumblers in cold water
    (c) placing the outer tumbler in hot water
    (d) hammering them vigorously
31. The quantity of heat required to raise the temperature of 2000 g of water from 10°to 50°C is
    (a) 80 cal
    (b) 80,000 cal
    (c) 8000 cal
    (d) none of these
32. A test tube containing some water is surrounded by melting ice (pure). Then the water in the test tube will
    (a) not freeze into ice
    (b) freeze into ice
    (c) boil ultimately
    (d) become steam ultimately
33. Glaciers always melt at the________________ first.
    (a) top surface
    (b) sides
    (c) bottom
    (d) middle surface

34. Heat flows as a result of difference of
    (a) temperature (c) mass
    (b) weight (d) none of these
35. The unit of specific heat is
    (a) cal °C (c) cal/g/°C
    (b) cal/g/°C (d) none of these
36. The unit of thermal capacity is
    (a) cal/°C (c) cal/g/°C
    (b) cal/g (d) none of these
37. The unit of latent heat is
    (a) cal–g (c) cal/g
    (b) cal/°C (d) none of these
38. If the thermal capacity of a body is infinity, then
    (a) heat can never be added to it
    (b) heat can never be extracted from it
    (c) the temperature of the body cannot be altered by adding or extracting any amount of heat
    (d) it has infinite amount of heat
39. Calorimeters are generally made of
    (a) copper (c) aluminium
    (b) brass (d) zinc
40. When 1 g of water at 100°C gets converted into steam at the same temperature, the change in volume is approximately
    (a) 1 cc (c) 1500 cc
    (b) 1000 cc (d) 1670 cc
41. The amount of heat required for the above operation is
    (a) 380 cal (c) 4.2 cal
    (b) 500 cal (d) none of these
42. One joule is approximately equal to
    (a) 0.28 cal (c) 0.24 cal
    (b) 0.32 cal (d) 4.2 cal
43. M g of ice at 0°C is to be converted to water at 0°C. If L is the latent heat of fusion of ice, the quantity of heat required for the above operation would be

(a) ML cal

(b) $\frac{M}{L}$

(c) $\frac{L}{M}$ cal

(d) none of these

44. Two bodies A and B are said to be in thermal equilibrium with each other, if

(a) heat flows from A to B

(b) heat flows from B to A

(c) both the bodies lose equal amounts of heat to the atmosphere

(d) heat does not flow from either A or B

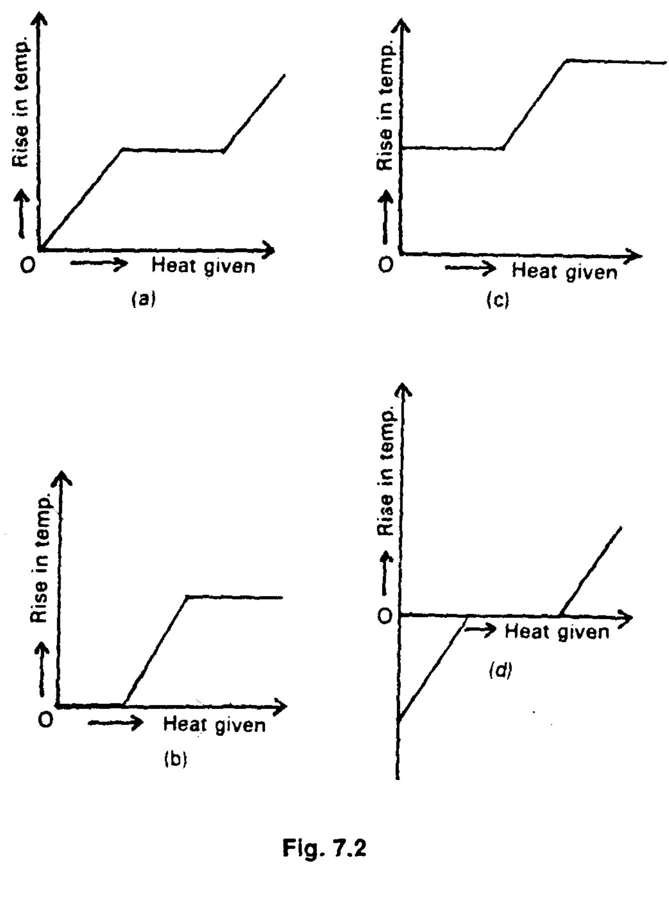


Fig. 7.2

45. 100 g of ice at – 15°C was heated. The rise in temperature of ice was plotted against the heat given to ice. Which of the following graphs (Fig. 7.2) correctly depicts this behaviour ?
    (a) a (c) c
    (b) b (d) d

46. If a substance contracts on heating, its coefficient of linear expansion is
    (a) +ve (c) zero
    (b) –ve (d) infinity

47. When air is saturated, it cannot hold
    (a) more water vapour (c) more carbon dioxide
    (b) more air (d) more oxygen

48. The units of RH are
    (a) kg– m^{-3} (c) kg– m^2
    (b) kg (d) none of these

49. If RH is high
    (a) we feel sultry (c) clothes do not dry easily
    (b) we perspire less (d) all the above are correct

50. When it is raining, the dew point is
    (a) 0°C (c) 50°C
    (b) 100°C (d) room temperature

51. At dew point, RH is
    (a) 10% (c) 50%
    (b) 20% (d) 100%

52. The most comfortable value for RH is
    (a) 10% (c) 50%
    (b) 30% (d) 90%

53. When the temperature of water rises, the rate of evaporation
    (a) increases
    (b) decreases
    (c) remains the same
    (d) first decreases then increases

54. The first thermometer was developed by
    (a) Joule (c) Galileo
    (b) Fahrenheit (d) Watt

55. Burning of a meteorite in the earth's atmosphere is an example of change of
    (a) heat energy into kinetic energy
    (b) kinetic energy into heat energy
    (c) kinetic energy into potential energy
    (d) potential energy into heat energy

56. Heat given (H) to a substance was plotted against rise in temperature (θ). Which of the following parts of the graph (Fig. 7.3), most correctly depicts the latent heat of the substance ?

    (a) AB   (c) CD
    (b) BC   (d) BC and DE

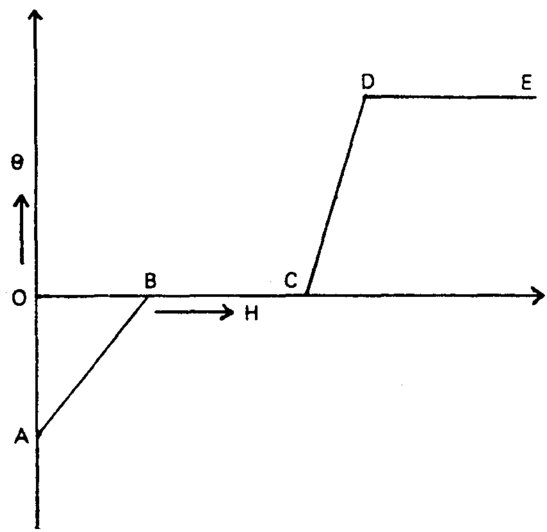


Fig. 7.3

57. Soda bottles are made of thick glass so that they can withstand the
    (a) pressure in summer
    (b) temperature in summer

(c) decrease in viscosity

(d) increase in potential energy

58. The relative humidity is 50%, if air contains

(a) 2.55 g of water vapour at 40°C

(b) 25.5 g of water vapour at 40°C

(c) 2.55 kg of water vapour at 40°C

(d) 25.5 kg of water vapour at 40°C

59. Relative humidity is the percentage of the

(a) absolute humidity value to the amount of humidity actually present

(b) increase of humidity/absolute humidity

(c) amount of humidity actually present to the absolute humidity value

(d) none of these

60. Evaporation is the process of changing liquid into vapour

(a) at any temperature

(b) above its boiling point

(c) at its boiling point

(d) below its boiling point

61. When we cool a gas below its condensation point, the KE of its molecules

(a) increases

(b) decreases

(c) remains the same

(d) first increases then decreases

62. A piece of ice at 0°C is added to a vessel containing water at 0°C, then

(a) all of the ice will melt

(b) some ice will melt

(c) no ice will melt

(d) the temperature will decrease further

63. At high temperature, the molecules of a substance

(a) move more vigorously

(b) move less vigorously

(c) become stationary

(d) are attracted strongly

64. Fahrenheit scale divides two fixed points into

(a) 180 parts

(b) 212 parts

(c) 100 parts

(d) 32 parts

65. Celsius scale divides two fixed points into

(a) 180 parts
(c) 100 parts
(b) 212 parts
(d) 32 parts

66. In hot water bottles, water is used because

(a) its specific heat is low
(c) it is cheap
(b) its specific heat is high
(d) it is easily available

67. Two rods, one of iron and the other of aluminium, are heated to the same temperature

(a) the iron rod will expand less
(b) the iron rod will expand more
(c) both rods will expand equally
(d) the iron rod will not expand at all

68. When steam condenses into water its

(a) temperature remains the same
(b) heat dissipates
(c) temperature increases
(d) temperature decreases

69. Two blocks of steel A and B, A being two times heavier than B, are at 40°C. The ratio of heat content of A to B is

(a) 1
(c) 2
(b) 4
(d) $\frac{1}{2}$

70. When 60 calories of heat are supplied to 15 g of water, the rise in temperature is

(a) 75°C
(c) 4°C
(b) 900°C
(d) 0.25°C

71. A 10 kg storage battery has an average specific heat of 0.2 Kcal/kg°C. When fully charged, the energy content of the battery is 1 Kcal. If the entire energy were used to raise the temperature, then the temperature would increase by

(a) 0.2°C
(c) 200°C
(b) 0.5°C
(d) 20°C

72. Water in a container is heated from 0°C to 10° C. Its volume

(a) increase for the full given range (from 0° C to 10°C)
(b) decreases up to 40°C, then increases

(c) increases up to 40°C, then decreases

(d) decrease for the full range (from 0°C to 10°C)

True or False Statements

1. One calorie is bigger than one joule.
2. The SI unit of heat is calorie.
3. Celsius scale is also known as the centigrade scale.
4. Normal temperature of a human body is 98.6°C.
5. The degree of hotness of coldness of a body is called its temperature.
6. Density of a substance decreases with increase in temperature.
7. The temperature at which pure water boils at standard atmospheric pressure is called the lower fixed point.
8. The temperature at which pure ice melts at normal atmospheric pressure is called the lower fixed point.
9. The specific heat of mercury is lowest.
10. The use of water as a heating and cooling agent is due to its low specific heat.
11. The thermal capacity of a body is equal to the product of its mass and latent heat.
12. When change of area is concerned, the expansion is called superficial expansion.
13. Heat content of steam is less than that of boiling water.
14. The latent heat of a body will change if Fahrenheit scale is used instead of the Celsius scale.
15. No dew is formed on windy nights.
16. All solids expand equally for the same rise in temperature.
17. It is correct to say that ice is colder than ice-cold water.
18. A blacksmith fixes a metal rim on the wooden rim of a bullock cart by heating it.
19. Specific heat of water and ice are same.
20. It is quite comfortable during rainy season due to high relative humidity.

21. Benzene is preferred to mercury as a thermometric substance since its expansion is six fold higher than that of mercury.
22. Upper and lower fixed points are marked by considering the respective temperatures at atmospheric pressure.
23. Loops are provided in order to avoid strain that would develop in the pipes during the change in temperature.
24. Under certain circumstances, the temperature of a substance does not rise even when it is heated.
25. Two brass rods of equal lengths having radius in the ratio 1 : 3 are heated through the same temperature. The increase in length would be different for both.

ANSWERS OBJECTIVE EVALUATION

1. (d)	2. (d)	3. (b)	4. (a)	5. (a)	6. (a)	7. (c)	8. (a)	9. (b)
10. (d)	11. (b)	12. (b)	13. (c)	14. (d)	15. (d)	16. (b)	17. (a)	18. (b)
19. (c)	20. (a)	21. (a)	22. (d)	23. (d)	24. (b)	25. (a)	26. (c)	27. (b)
28. (a)	29. (a)	30. (c)	31. (b)	32. (a)	33. (c)	34. (a)	35. (b)	36. (a)
37. (c)	38. (c)	39. (a)	40. (d)	41. (d)	42. (c)	43. (a)	44. (d)	45. (d)
46. (b)	47. (a)	48. (d)	49. (d)	50. (d)	51. (d)	52. (c)	53. (a)	54. (c)
55. (b)	56. (d)	57. (a)	58. (b)	59. (c)	60. (d)	61. (b)	62. (c)	63. (a)
64. (a)	65. (c)	66. (b)	67. (a)	68. (b)	69. (c)	70. (c)	71. (b)	72. (b)

ANSWERS TRUE/FALSE

1. T	2. F	3. T	4. F	5. T	6. T	7. F	8. T	9. T
10. F	11. F	12. T	13. F	14. F	15. F	16. F	17. T	18. T
19. F	20. F	21. F	22. T	23. T	24. T	25. F		

UNIT EIGHT
LIGHT

REVIEW CONCEPTS

Light is defined as radiant energy. It produces sensation of sight.

Rectilinear propagation of light means that light travels in a straight line.

Reflection The process of turning back of light to the first medium from the surface of separation of two media is called reflection.

Laws of reflection

(i) The angle of incidence is equal to the angle of reflection.
(ii) The incident ray, reflected ray and the normal to the point of incidence at the reflecting surface, all lie in one and the same plane.

Spherical mirrors are those whose reflecting surfaces are a part of a sphere. The centre of the sphere, of which the mirror forms a part is known as the centre of curvature. The central point on the surface of the spherical mirror is known as the pole of the mirror. Refer to Fig. 8.1 for various terms connected with mirrors.

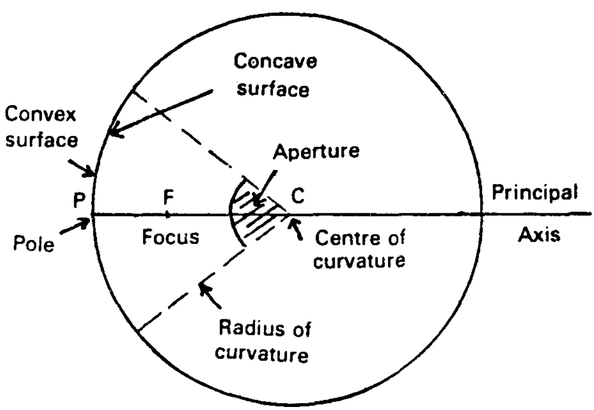


Fig. 8.1 Important features of spherical mirrors

The *principal axis* is the line joining the centre of curvature and the pole of the mirror (and extends in both directions)

Principal focus is a point on the principal axis where incident rays parallel to the principal axis, after reflection from the spherical mirror meet or appear to meet.

Focal length is the distance between the principal focus and the pole of the mirror.

Concave mirror : It forms a real and inverted image when an object is placed anywhere between infinity and the focus of the mirror. Between focus and pole, the image formed is virtual and erect.

Convex mirror : It always forms a virtual and erect image.

Real image is the one which can be taken on a screen and is formed due to the actual intersection of reflected rays.

Virtual image is the one which cannot be taken on a screen and is formed when the two rays meet on producing them backward.

Sign convention used for spherical mirrors.

(i) All distances are measured from the pole of the mirror as origin.

(ii) Distances taken in the direction of the incident ray are positive.

(iii) Distances taken in the direction opposite to the incident ray are negative.

(iv) Distance upward and normal to the principal axis are taken to be positive.

(v) Distances downward and normal to the axis are taken to be negative.

(vi) For both concave and convex mirrors, the distance of the object (u) is always negative.

(vii) For concave mirror, the focal length is negative and for convex mirror it is positive.

Relation between focal length and radius of curvature. For spherical mirrors radius of curvature is double the focal length.

Magnification is the ratio of the size of the image to the size of the object.

Lens : A transparent medium bounded by two non-parallel curved surfaces or by one plane surface and another curved surface is called a lens. Thus, a lens is a piece of transparent material bounded by two refracting surfaces, at least one of which is curved. The property of a lens is to converge or diverge the rays of light incident on it.

Convex lens : It is a converging lens. It forms a real image for all positions of the object between infinity and focus. Only when the object lies between focus and optical centre, it forms a virtual image.

Concave lens : It is a diverging lens. It always forms a virtual

image, whatever may be the position of the object. Sign convention : Same as for mirrors.

Kinds of converging lenses : There are three kinds of converging lenses, viz., double convex, plane convex and concave-convex. They are shown in Fig. 8.2 (i).

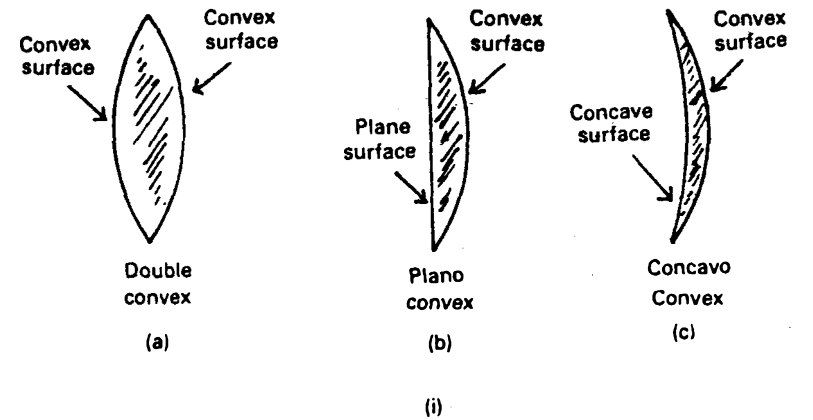


Fig. 8.2 (i) Various types of convex surfaces

Kinds of diverging lenses : They are also of three kinds viz., double concave, plane-concave and convexo-concave. They are shown in Fig. 8.2 (ii).

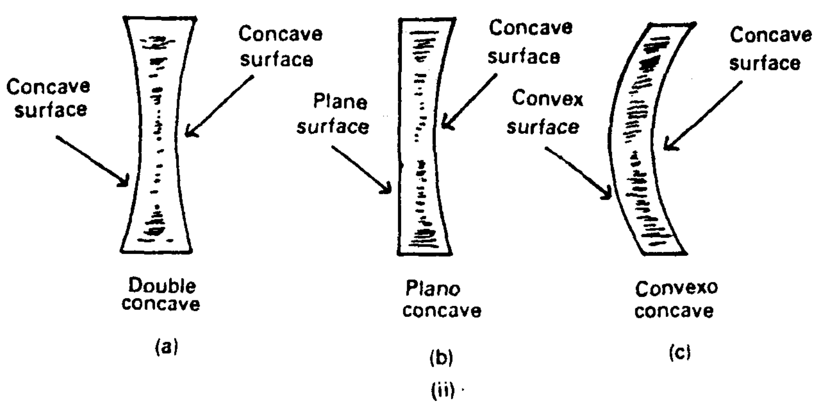


Fig. 8.2 (ii) Various types of concave surfaces

The principal axis is the line joining the centre of curvatures of two surfaces of a lens.

The focal length of a lens is the distance between the principal focus and the optical centre of the lens.

The focal plane is any plane perpendicular to the principal axis and passing through the principal focus.

The power of a lens is the reciprocal of its focal length.

Defects of the eye :

(i) Myopia or shortsightedness : Any person suffering from myopia can see nearby objects clearly but not the ones far away. For the remedy of myopia, concave lenses of suitable focal length are used.

(ii) Hypermetropia or long sightedness : Any person suffering from hypermetropia can see far away objects clearly but not the nearer ones. For the remedy of hypermetropia convex lenses are used.

Simple microscope is a simple magnifying glass of a short focal length mounted in a circular frame with a handle. It works on the fact that a convex lens forms a virtual, erect and magnified image of an object placed at a distance less than its focal length.

The magnifying power (M) of a simple microscope is defined as the ratio of the angle subtended by the image at the eye, to the angle subtended by the object at the eye, when the object is placed at the least distance of distinct vision.

A compound microscope is an instrument to see very small objects placed near it. It forms a virtual, erect and magnified image.

The magnifying power of a compound microscope is defined as the ratio of the angle subtended by the object seen without the microscope, when both the object and the final image are at the least distance of distinct vision.

Astronomical telescope is an instrument to see celestial bodies (far away objects) clearly.

The magnifying power of a telescope in normal adjustment is defined as the ratio of the angle subtended by the image at the eye as seen through the telescope, to the angle subtended by the object at the eye as seen without the telescope, when both the object and the image are at infinity.

Dispersion is the splitting of white light. The colour pattern obtained is called the spectrum. Violet colour suffers maximum deviation and red suffers minimum deviation.

Colour of the object depends upon the colour of the incident light that falls upon them and the colour of the light reflected by that object.

Primary colours are three namely red, blue and green. All the

colours of white light spectrum can be obtained by mixing of two or all the three primary colours in appropriate proportions.

Colour blindness : A person who cannot distinguish between various colours is said to be colour blind. A colour blind person lacks either one type, two types or all the three types of cones in the retina of his eye.

Formulae

$$R = 2f \text{ or } f = R/2$$

where R = radius of curvature and
f = focal length

Mirror formula

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

where u = distance of the object
v = distance of the image
f = focal length

Magnification

$$M = \frac{I}{O} = \frac{-v}{u}$$

where I = size of the image
O = size of the object
v = distance of the image
and u = distance of the object

Lens formula

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

where symbols have got their usual meaning.

Power of a lens

$$P = \frac{1}{f \text{ (in metres)}}$$

or

$$P = \frac{100}{f \text{ (in cm)}}$$

where f = focal length and
P = power of the lens

Magnifying power for a lens

$$M = 1 + \frac{D}{f}$$

where D = the least distance of distinct vision and

f = focal length

Magnifying power of a compound microscope

$$M = M_o \times M_e$$

where M_o = Magnification produced by the objective and

M_e = Magnification produced by the eye-piece

$$M = \frac{L}{f_o}\left(1 + \frac{D}{f_e}\right) \text{ or } M = \frac{D \times L}{f_e \times f_o}$$

where L = length of the microscope

f_o = focal length of the objective

f_e = focal length of the eye-piece, and

D = distance of distinct vision

Magnifying power of a telescope

$$M = \frac{f_o}{f_e}$$

Power of combination of lenses

$$P = P_1 + P_2 + P_3 + \ldots + \ldots$$

where P_1, P_2, P_3, . . . are the powers of the individual lenses.

NUMERICAL PROBLEMS (SOLVED)

EXAMPLE 1 An object is placed at a distance of 10 cm from the pole of a concave mirror. Its image is formed at 6 cm from its pole. Calculate the focal length of the mirror.

Solution: Given,

Distance of the object (u) = 10 cm

= – 10 cm (according to sign convention)

Distance of the image (v) = 6 cm

= – 6 cm (sign convention)

To calculate : Focal length (f) = ?

Formula to be used : $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$

Substituting the given values,

$$\frac{1}{f} = \frac{1}{-10} + \frac{1}{-6}$$

$$= \frac{-6 - 10}{60} = \frac{-16}{60}$$

$$f = -3.75 \text{ cm}$$

EXAMPLE 2 An object is placed at a distance of 6 cm from a convex mirror of focal length 12 cm. Find the position and nature of the image.

Solution: Given,

Distance of the object (u) = -6 cm

Focal length (f) = $+12$ cm

To calculate : (i) Position of the image (v) = ?

(ii) Nature of the image = ?

Formula to be used : $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$

or $\frac{1}{v} = \frac{1}{f} - \frac{1}{u}$

Substituting the given values

$$\frac{1}{v} = \frac{1}{12} - \left(-\frac{1}{6}\right)$$

$$= \frac{1}{12} + \frac{1}{6} = \frac{1+2}{12} = \frac{3}{12}$$

or $$v = \frac{12}{3} = 4 \text{ cm}$$

Nature : Virtual, erect and small in size.

EXAMPLE 3 A concave mirror produces a real image of height 2 cm of an object from 0.5 cm placed 10 cm away from the mirror. Find the position of the image and focal length of the mirror ?

Solution: Given,

Distance of the object (u) = -10 cm

Size of the image (I) = -2 cm

Size of the object (O) = 0.5 cm

To calculate : (i) Distance of the image (v) = ?

(ii) Focal length (f) = ?

Formula to be used : (i) $(M) = \frac{I}{O}$

(ii) $M = -\dfrac{v}{u}$

and (iii) $\dfrac{1}{v} + \dfrac{1}{u} = \dfrac{1}{f}$

Since we are given I and O, we will first find out M and then from formula (ii) we will find out v

From first formula $\quad M = \dfrac{I}{O}$

$$M = \frac{-2}{0.5} = -4$$

Putting this value of M in formula (ii) we get,

$$-4 = -\frac{v}{-10} \Rightarrow v = -40 \text{ cm}$$

Now to find f we will use formula (iii)

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$$

$$\frac{1}{f} = -\frac{1}{40} + \left(-\frac{1}{10}\right)$$

$$= -\frac{1}{40} - \frac{1}{10}$$

$$\frac{1}{f} = \frac{-1-4}{40} = \frac{-5}{40}$$

or $\quad f = -8 \text{ cm}$ and $v = -40 \text{ cm}$

EXAMPLE 4 A dentist uses a small concave mirror of focal length 3.0 cm and holds it at a distance of 2 cm from the tooth. What is the magnification of the image ?

Solution: Given

Focal length of the mirror (f) = – 3.0 cm

Distance of the object (u) = – 2.0 cm

To calculate : Magnification (M) = ?

Formula to be used : $\quad M = -\dfrac{v}{u}$

Since in this case we do not know the value of v, so first of all we will use the formula,

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$$

to calculate v and then we will find out M

$$\therefore \qquad \frac{1}{v} = \frac{1}{f} - \frac{1}{u}$$

Substituting the given values we get,

$$\frac{1}{v} = -\frac{1}{3} - \left(-\frac{1}{2}\right) = -\frac{1}{3} + \frac{1}{2}$$

$$= \frac{-2+3}{6} = \frac{1}{6}$$

$$\therefore \qquad v = 6 \text{ cm}$$

Since v is positive, the image is virtual.

Now, $$M = -\frac{v}{u} = -\frac{6}{-2} = 3$$

i.e., the image is three times the size of the object.

EXAMPLE 5 How far should an object be held from a concave mirror of focal length 40 cm so as to get an image magnified three times ?

Solution: Given,

Focal length (f) = – 40 cm

Magnification (M) = 3

To calculate : Distance of the object (u) = ?

Since, the nature of the image so formed is not specified so two cases arise here,

Case I When the image formed is real.

Case II When the image formed is virtual.

Formula to be used : $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

But only f and M are given, therefore we cannot use this formula directly so we will first use the formula

$$M = \frac{v}{u}$$

$$\therefore \qquad 3 = \frac{v}{u} \quad \Rightarrow \quad v = 3u$$

Case I — When the image formed is real

$$v = +3u$$

Substituting the given values we get,

$$\frac{1}{3u} + \frac{1}{u} = \frac{1}{-40}$$

$$\frac{1+3}{3}u = \frac{1}{-40}$$

$$= \frac{3u}{4} = -40$$

Case II — When image formed is virtual $v = -34$ cm.

Substituting the given values, we get

$$-\frac{1}{34} + \frac{1}{u} = -\frac{1}{40}$$

$$\frac{-1+3}{3u} = -\frac{1}{40}$$

$$\frac{2}{3u} = -\frac{1}{40}$$

$$-80 = 3u \quad \text{or} \quad \frac{-80}{3} = u$$

$$u = -26.6 \text{ cm}$$

Hence if the object is held at a distance of 53.5 cm, a real image thrice in size is obtained. Also a virtual image of thrice the size is obtained if the distance of the object is 26.6 cm.

EXAMPLE 6 A concave mirror of focal length 10 cm is kept in front of an object at a distance of 50 cm from it. If the object is 1.0 cm high, what will be the size of the image ?

Solution: Given,

Focal length (f) = − 10 cm

Distance of the object (u) = − 50 cm

Size of the object (O) = + 1 cm

To calculate : Size of the image (I) = ?

Formula to be used : $M = \frac{-I}{O}$ (i)

But to calculate (I), we will have to find out M and to calculate M, we must know v.

Our first problem is to determine v.

We know that $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{u}$$

Substituting the value of f and u we get

$$\frac{1}{v} = -\frac{1}{10} - \left(-\frac{1}{50}\right)$$

$$= -\frac{1}{10} + \frac{1}{50}$$

$$\frac{1}{v} = \frac{-5+1}{50}$$

=> $$v = \frac{-50}{4}$$

$$v = -12.5 \text{ cm}$$

Also we know that,

$$M = \frac{v}{u}$$

Substituting the value of v and u, we get

$$M = -\frac{-12.5}{-50} = -\frac{1}{4}$$

Now putting the value of M and O in equation (i) we get,

$$-\frac{1}{4} = \frac{-I}{1.0}$$

=> $$I = 0.25 \text{ cm}$$

i.e., the size of the image is 0.25 cm.

EXAMPLE 7 How far from a lamp must a concave mirror of focal length 3.0 m be placed in order to throw its image on the screen 8.0 m from the lamp ?

Solution: Given,

Focal length (f) = -3.0 m

Distance of the image (v) = -8.0 m

To calculate : Distance of the object (u) = ?

Formula to be used : $$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$$

or $$\frac{1}{u} = \frac{1}{f} - \frac{1}{v}$$

Substituting the given values, we get

$$\frac{1}{u} = \frac{-1}{3.0} - \left(-\frac{1}{8.0}\right)$$

$$= -\frac{1}{3.0} + \frac{1}{8.0}$$

$$= \frac{-8+3}{24} = \frac{-5}{24}$$

or $$u = \frac{-24}{5} = -4.8 \text{ m}$$

$$u = -4.8 \text{ m}$$

EXAMPLE 8 An object is located 20 cm in front of a concave mirror of radius of curvature 60 cm. Find the position and nature of the image formed.

Solution: Given,

Distance of the object $(u) = -20$ cm

Radius of curvature $(r) = 60$ cm

To calculate : (i) Position of the image $(v) = ?$

(ii) Magnification $(M) = ?$

Formula to be used : (i) $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$

or $$\frac{1}{v} = \frac{1}{f} - \frac{1}{u}$$

(ii) $M = -\frac{v}{u}$

Since we are not given f. So in order to calculate f we will first use the formula

$$r = 2f$$

or $$f = \frac{r}{2}$$

Substituting the value of r in the above equation, we get

$$f = -\frac{60}{2}$$

$$f = -30 \text{ cm}$$

Now put this value of f and u in the mirror formula,

$$\frac{1}{v} = -\frac{1}{30} - \left(-\frac{1}{20}\right)$$

$$= -\frac{1}{30} + \frac{1}{20}$$

$$= \frac{-2+3}{60} = \frac{1}{60}$$

=> $$v = 60 \text{ cm}$$

The positive value of $v = 60$ cm means the image is at the back of the mirror, i.e., virtual, erect and enlarged.

Also magnification

$$M = \frac{-v}{u} = \frac{-60}{-20} = 3$$

i.e., image is 3 times the size of the object.

EXAMPLE 9 If we need a magnification of 375 from a microscope of tube length 15 cm and an objective of focal length 0.5 cm, what focal length eye-piece should we use ?

Solution: Given,

Magnification (M) = 375

Length of the tube (L) = 15 cm

Focal length of the objective (f_o) = 0.5 cm

Distance of distinct vision (D) = 25 cm (for a normal person)

To calculate : Focal length of the eye-piece (f_e) = ?

Formula to be used : $M = \frac{D \times L}{f_o \times f_e}$

or $f_e = \frac{D \times L}{M \times f_o}$

Substituting the given value, we get

$$f_e = \frac{25 \times 15}{375 \times 0.5}$$

$$= \frac{25 \times 15 \times 10}{375 \times 5} = 2$$

$$f_e = 2 \text{ cm}$$

EXAMPLE 10 A diverging or concave lens of focal length 15 cm forms an image 10 cm from the lens. Draw a scale diagram and prove that the object is placed 30 cm away from the lens. Use a scale of 1 : 5.

Solution: Given,

Distance of the image (v) = 10 cm

Focal length (f) = 15 cm

To calculate : Distance of the object (u) = ?

Formula to be used : $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

or $\frac{1}{u} = \frac{1}{v} - \frac{1}{f}$

Using sign convention, v and f are both negative ($\because$ focal length

of a concave lens is always negative and since it forms a virtual image v is also negative).

$\therefore \quad v = -10$ cm and $f = -15$ cm

Substituting the given values, we get

$$\frac{1}{u} = \frac{1}{-10} - \left(-\frac{1}{15}\right)$$

$$= -\frac{1}{10} + \frac{1}{15}$$

$$\frac{1}{u} = \frac{-3+2}{30} = -\frac{1}{30}$$

or $\quad u = -30$ cm

i.e., the object is at a distance of 30 cm from the lens. The negative sign is due to the sign convention.

(Distance OB = 6 cm, i.e., $6 \times 5 = 30$ cm. That means the object is placed at a distance of 30 cm from the lens.)

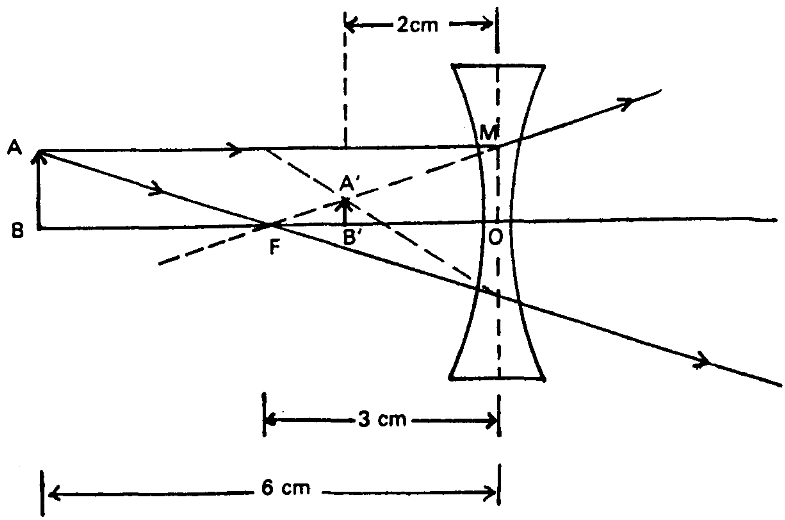


Fig. 8.3 Scale diagram

EXAMPLE 11 An object 5 cm high is kept 25 cm from a converging lens of focal length $f = 10$ cm. Draw a suitable scale of 1 : 5 and find the position and size of the image formed. Is the image real or virtual ?

Solution: Given,

Distance of the object (u) = $-$ 25 cm

Focal length (f) = + 10 cm

Size of the object (O) = 5 cm

To calculate : (i) Distance of the image (v) = ?

(ii) Size of the image (I) = ?

Formula to be used : (i) $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

or $$\frac{1}{v} = \frac{1}{f} + \frac{1}{u}$$

(ii) $\frac{I}{O} = \frac{v}{u}$

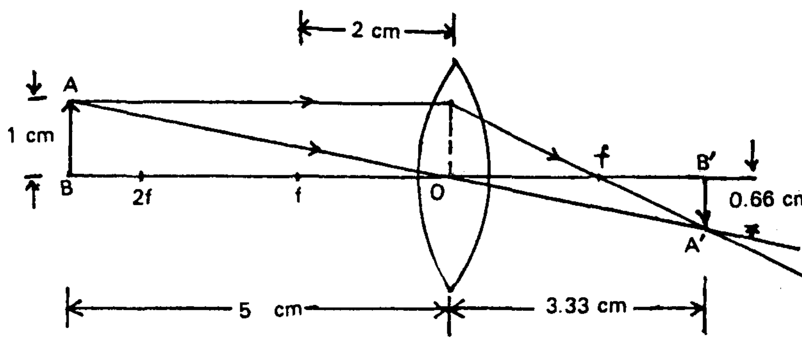


Fig. 8.4

(i) Substituting the given values, we get,

$$\frac{1}{v} = \frac{1}{10} + \left(-\frac{1}{25}\right)$$

$$= \frac{1}{10} - \frac{1}{25}$$

$$= \frac{5-2}{50} = \frac{3}{50}$$

or $$v = \frac{50}{3} \text{ cm}$$

The positive value of v means the image is formed on the other side of the lens.

It is real and inverted.

(ii) Size of the image $\quad (I) = \dfrac{v \times O}{u}$

$$= \frac{50}{3} \times \frac{5}{-25} = \frac{-10}{3}$$

=> $\quad I = -3.33$ cm

EXAMPLE 12 An object 5 cm high is placed at a distance of 30 cm from a convex lens of focal length 15 cm. Find the position and nature of the image.

Solution: Given,

Size of the object $(O) = +5$ cm

Distance of the object $(u) = -30$ cm

Focal length $(f) = +15$ cm

To calculate : (i) Distance of the image $(v) = ?$

(ii) Size of the image $(v) = ?$

Formula to be used : (i) $\dfrac{1}{f} = \dfrac{1}{v} - \dfrac{1}{u}$

(ii) $\dfrac{I}{O} = \dfrac{v}{u}$

Substituting the given values in formula (i), we get

$$\frac{1}{v} = \frac{1}{15} + \left(-\frac{1}{30}\right) = \frac{1}{15} - \frac{1}{30}$$

=> $\quad \dfrac{1}{v} = \dfrac{1}{30}$ or $v = 30$ cm

(ii) $\quad \dfrac{I}{50} = \dfrac{30}{-30} \quad => \quad I = \dfrac{-150}{30}$

or $\quad I = -5$ cm

i.e., the image is below the principal axis and is of the same size as the object.

EXAMPLE 13 An object 4 cm high is placed at a distance of 15 cm in front of a concave lens of power – 10 dioptre. Find the size of the image.

Solution: Given,

Size of the object $(O) = +4$ cm

Distance of the object (u) = – 15 cm

Power of the lens (P) = – 10 dioptre

To calculate : Size of the image (I) = ?

Formula to be used : $\frac{I}{O} = \frac{v}{u}$

But to calculate I, we will have to find out f and v first of all.

Calculation of f : We know that

$$P = \frac{1}{f \text{ (in metres)}}$$

$$-10 = \frac{1}{f}$$

=> $$f = -\frac{1}{10} \text{ m}$$

$$f = -10 \text{ cm}$$

Calculation of v

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

or $$\frac{1}{v} = \frac{1}{f} + \frac{1}{u}$$

Substituting the values of f and u we get,

$$\frac{1}{v} = -\frac{1}{10} + \left(-\frac{1}{15}\right)$$

$$= -\frac{1}{10} - \frac{1}{15}$$

$$= \frac{-3-2}{30} = \frac{-5}{30}$$

or $$v = -6 \text{ cm}$$

Now we can make use of the formula

$$\frac{I}{O} = \frac{v}{u} = I = \frac{v \times O}{u}$$

Putting the value of O, v and u we get,

$$I = \frac{(-6) \times (+4)}{(-15)}$$

$$= \frac{24}{15} = 1.6 \text{ cm}$$

EXAMPLE 14 Two lenses of focal length + 25 cm and – 10 cm (convex

Focal length of the objective (f_o) = 100 cm

To calculate : (i) Focal length of the eye-piece (f_e) = ?

(ii) Power of the eye-piece (P) = ?

Formula to be used : (i) $M = \frac{f_o}{f_e}$

or $f_e = \frac{f_o}{M}$

(ii) $P = \frac{1}{f \text{ (in metres)}}$

(i) Substituting the value of f_o and M we get,

$$f_e = \frac{100}{20} = 5 \text{ cm}$$

(ii) Power (P) = 100/5 = 20 dioptre

EXAMPLE 18 In a simple microscope, the focal length of the lens is 3.0 cm. Find its magnifying power.

Solution: Given,

Focal length (f) = 3.0 cm

Distance of distinct vision (D) = 25 cm

To calculate : Magnification (M) = ?

Formula to be used : $M = 1 + \frac{D}{f}$

Substituting the given values, we get

$$M = 1 + \frac{25}{3}$$

$$M = 1 + 8.33 = 9.33$$

EXAMPLE 19 A person who cannot see objects nearer than 1.0 m from his eyes, wants to read a book placed at a distance of 25 cm clearly. What kind of a lens would he require ? What will be the power of such a lens ?

Solution: Given,

Distance at which the person wants to read (u) = – 25 cm

Distance of the actual near point (v) = – 1 m = – 100 cm

To calculate : (i) Power of the lens (P) = ?

(ii) Nature of the lens = ?

Formula to be used : $P = \dfrac{1}{f \text{ (in metres)}}$

(i) But to calculate P, we first know f. Therefore substituting the given values in the lens formula

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

we get,

$$\frac{-1}{100} - \left(-\frac{1}{25}\right)p = \frac{1}{f}$$

$$= -\frac{1}{100} + \frac{1}{25} = \frac{1}{f}$$

$$= \frac{-1+4}{100} = \frac{1}{f}$$

=> $f = 33.3$ cm

Thus,

$$P = \frac{100}{33.3}$$

=> $P = +\ 3.0$ dioptre

(ii) The positive sign indicates that the lens used is a convex lens.

EXAMPLE 20 A person can see clearly up to 3.0 m. Describe the type of lens that should be used so that he can see up to 12 m clearly.

Solution: Given,

Distance of the object (u) = $-$ 12 m

Distance of the image (v) = $-$ 3 m

To calculate : (i) Focal length (f) = ?

(ii) Power of the lens (P) = ?

Formula to be used : (i) $\dfrac{1}{v} - \dfrac{1}{u} = \dfrac{1}{f}$

(ii) $P = \dfrac{1}{f \text{ (in metres)}}$

(i) $$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

Substituting the given values,

$$\frac{1}{-3} - \left(-\frac{1}{12}\right) = \frac{1}{f}$$

or $$\frac{1}{f} = \frac{-4+1}{12}$$

$$\frac{1}{f} = \frac{-3}{12}$$

$\Rightarrow$ $$f = -4.0 \text{ m}$$

Negative sign indicates that the lens used should be concave.

(ii) $$\text{Power } (P) = \frac{1}{f \text{ (in metres)}}$$

$$P = \frac{1}{-40}$$

$$P = -0.25 \text{ dioptre}$$

NUMERICAL PROBLEMS (UNSOLVED)

1. A concave mirror has a radius of curvature of 48 cm. What is the magnitude of its focal length ? (Ans. 24 cm)
2. The magnitude of focal length of a concave mirror is 26 cm. What is its radius of curvature ? (Ans. 52 cm)
3. An object and its image in a concave mirror are of the same height when the object is at a distance of 15 cm from the mirror. What is the focal length of the mirror ? (Ans. –7.5 cm)
4. An object is placed at a distance of 20 cm from a concave mirror whose focal length is 4 cm. What is the type of image and where is it situated ?

   (Ans. Real, inverted and at a distance of 5 cm from the mirror, on the side of the object)
5. An image produced by a concave mirror is half the size of the object. If the object is moved 5 cm away from the mirror, the image will be one-fourth the size of the object. What will be the focal length of the concave mirror ? (Ans. 2.5 cm)
6. When a long needle was set up in front of a concave mirror, it was found that the image was one-half the size of the needle and at a distance of 90 cm from it. What was the distance of the object from the mirror ? (Ans. –10 cm)
7. An object is placed in front of a concave mirror of focal length 30 cm and an image magnified three times is obtained. Calculate the possible positions of the object. (Ans. – 40 cm, –20 cm)
8. A concave mirror of focal length 10 cm is kept in front of an object, at a distance of 50 cm from it. If the object is 1 cm in height, what will be the size of the image ? (Ans. 0.25 cm)

9. A person with myopic eyes is not able to see objects beyond 3 m. Determine the nature, focal length and power of the correcting lens. (Ans. Divergent, –3 m, –3.3 D)

10. An object of 4.5 cm height is placed 20 cm from a convex lens of focal length 12 cm. Find the nature, position and heigth of the image.

    (Ans. The image is 30 cm from the convex lens, and located on the other side of the lens. It is real, inverted and 6.75 cm high)

11. Find the position and the nature of the image formed by a concave lens of focal length 15 cm, of an object placed at a distance of 5 cm in front of it. What is its magnification ?

    (Ans. The image is virtual and on the same side as the object. The magnification is 0.75)

12. It is required to throw an image, magnified two times, on a screen placed at a distance of 6 cm from the object. Find the focal length and nature of the lens required.

    (Ans. 19.33 cm, Convex)

13. A real image, exactly 1/5th the size of the object, is formed at a distance of 18 cm from a lens. Find the focal length of the lens.

    (Ans. + 15 cm)

14. What is the power of the convex lens whose focal length is 150 cm ? (Ans. + 0.67 D)

15. A long-sighted person has a distance of distinct vision of 40 cm. Find the nature and the focal length of the lens used by him to read a book 20 cm from the eye, using spectacles.

    (Ans. f = + 40 cm, Convex lens)

16. What power of a lens will change the reading distance from 1 m to 0.25 m ? (Ans. + 5 D)

17. A convex lens of focal length 0.20 m is placed in contact with a concave lens of focal length 0.25 m. What is the nature of the combination. Also find out the focal length of the combination.

    (Ans. Convex, 1 m)

18. An object 2 cm high is placed at a distance of 15 cm from a concave lens of focal length 10 cm. Find the position and size of the object. (Ans. – 6 cm, 0.8 cm)

OBJECTIVE EVALUATION

1. The mirror used in automobiles to see the rear field of view is
   (a) concave (c) plane
   (b) convex (d) none of these
2. A mirror having a very wide field of view must be
   (a) concave (c) plane
   (b) convex (d) none of these
3. The mirror used in search lights is
   (a) concave (c) plane
   (b) convex (d) none of these
4. A real image, equal in size to the object, is obtained when the object is placed at the centre of curvature in front of a
   (a) concave mirror (c) convex mirror
   (b) plane mirror (d) none of these
5. In order to have a very wide field of view, the mirror used in cars is
   (a) convex (c) concave
   (b) plane (d) none of these
6. Shaving mirrors are
   (a) convex mirrors (c) plane mirrors
   (b) concave mirrors (d) none of these
7. The relation between u, v and f is
   (a) $f = \frac{uv}{u - v}$ (c) $f = \frac{u \times v}{u + v}$
   (b) $f = \frac{u + v}{u \times v}$ (d) none of these
8. If we say that the focal length of a spherical mirror is n times its radius of curvature, then n must be
   (a) 2.0 (c) 0.2
   (b) 1.5 (d) none of these
9. The magnification produced by a concave mirror
   (a) is always more than one
   (b) is always less than one
   (c) is always equal to one
   (d) may be less than or greater than one.

10. Choose the correct relation between u, v and r.

(a) $r = \dfrac{2uv}{u + v}$

(b) $r = \dfrac{2}{u + v}$

(c) $r = \dfrac{2(u + v)}{(uv)}$

(d) none of these

11. Which is the wrong statement out of the following ?
(a) A concave mirror can give a virtual image
(b) A convex mirror can give a virtual image
(c) A concave mirror can give a diminished virtual image
(d) A convex mirror cannot give a real image

12. An inverted image can be seen in a convex mirror,
(a) under no circumstances
(b) when the object is very far from the mirror
(c) when the object is at a distance equal to the radius of curvature of the mirror
(d) when the distance of the object from the mirror is equal to the focal length of the mirror

13. The ratio of the size of the image to the size of the object is known as
(a) the focal plane
(b) the transformation ratio
(c) the efficiency
(d) none of these

14. The unit of magnification is
(a) m
(b) m^2
(c) m^{-1}
(d) none of these

15. The laws of reflection are true for
(a) the plane mirror only
(b) the concave mirror only
(c) the convex mirror only
(d) all reflecting surfaces

16. A virtual image is one which
(a) can be taken on a screen
(b) cannot be taken on a screen
(c) sometimes can be and sometimes cannot be taken on a screen
(d) is formed only by a concave mirror

17. When an object is placed between the focus and the pole of a concave mirror, the image formed is
    (a) real, inverted and small
    (b) real, inverted and same size
    (c) real, inverted and enlarged
    (d) virtual, erect and enlarged
18. The line joining the pole and the centre of curvature of a mirror is called the
    (a) aperture (c) principal axis
    (b) principal section (d) pole
19. In order to get a diminished virtual image, the object can be placed anywhere in front of a
    (a) concave mirror (c) convex mirror
    (b) plane mirror (d) none of these
20. The mirror used by dentists to concentrate light on the tooth to be examined is a ____________ mirror.
    (a) concave (c) convex
    (b) plane of concave (d) plane
21. The unit of power of a lens is
    (a) metre (c) dioptre
    (b) dyne (d) none of these
22. The least distance of distinct vision for a normal person is about
    (a) 1 m (c) 0.25 m
    (b) 0.5 m (d) none of these
23. The focal length of a lens is 50 cm. Its power would be
    (a) 50 dioptres (c) 20 dioptres
    (b) 2 dioptres (d) none of these
24. The unit of refractive index is
    (a) metre (c) dioptre
    (b) degree (d) it has no units
25. A simple magnifying glass consists of a
    (a) concave lens
    (b) convex lens of large focal length
    (c) convex lens of small focal length
    (d) plane mirror only

26. The eye lens is a
    (a) transparent double-convex lens
    (b) transparent double-concave lens
    (c) transparent concavo-convex lens

27. The eye lens contains a watery liquid called the
    (a) aqueous humor (c) vitreous humor
    (b) peroxide (d) none of these

28. Long-sightedness is caused by the eyeball being too short. It can be corrected by the use of a
    (a) convergent lens (c) divergent lens
    (b) plane mirror (d) none of these

29. Astigmatism occurs when the cornea does not have a truly spherical shape. This defect can be cured by the use of a
    (a) concave lens (c) convex lens
    (b) cylindrical lens (d) plano-convex lens

30. The power of a lens being + 4 dioptres suggests that it is a
    (a) convex lens (c) concave lens
    (b) plano-convex lens (d) none of these

31. When an object move towards a convex lens the size of the image
    (a) decreases
    (b) increases
    (c) first decreases then increases
    (d) remains the same

32. When a object approaches a convex lens from infinity, the image formed by it shifts
    (a) away from the lens
    (b) towards the lens
    (c) first away and then towards the lens
    (d) none of these

33. The amount of light entering in the eye is controlled by the
    (a) pupil (c) iris
    (b) cornea (d) eye lens

34. The liquid contained in the eye lens is called
    (a) peroxide (c) vitreous humor
    (b) aqueous humor (d) none of these

35. The screen behind the eye lens is called the
    (a) iris
    (b) ciliary muscle
    (c) retina
    (d) pupil

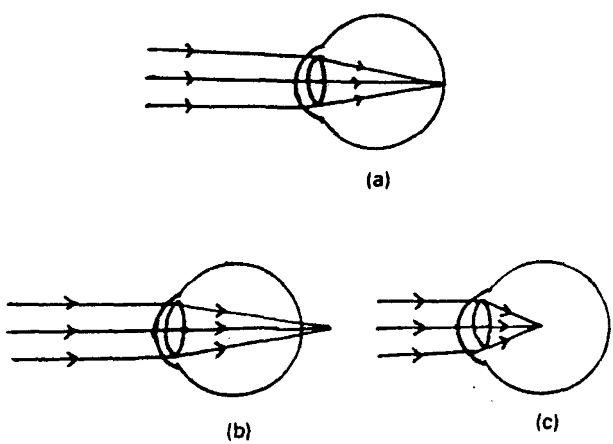
36. Cornea is a transparent spherical structure which
    (a) reflects light
    (b) scatters light
    (c) refracts light
    (d) none of these

37. The image on the retina remains for
    (a) 20 s
    (b) 10 s
    (c) $\frac{1}{10}$ s
    (d) $\frac{1}{20}$ s

38. The middle vascular coat that darkens the eye chamber and prevents refraction by absorbing the light rays is the
    (a) choroid
    (b) sclera
    (c) retina
    (d) cornea

39. The amount of light entering the eye is controlled by the
    (a) iris
    (b) cornea
    (c) pupil
    (d) crystalline lens

40. Figs. 8.5 (a), (b), and (c) respectively, indicate the point of focus in case of
    (a) the normal eye, the hypermetropic eye and myopic eye
    (b) the hypermetropic eye, the myopic eye and the normal eye



Figs. 8.5 (a) (b) (c)

(c) the normal eye, the myopic eye and the hypermetropic eye

(d) the myopic eye, the normal eye and the hypermetropic eye

41. How should people wearing spectacles work with a microscope ?

(a) They should keep on wearing their spectacles

(b) They should never use the microscope

(c) They should take off their spectacles

(d) They may either put on their spectacles or they may take off their spectacles

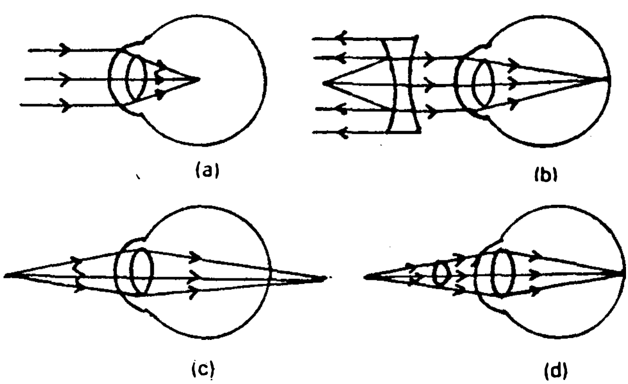
42. Figs. 8.6 (a), (b), (c) and (d) respectively correspond to

(a) the short-sighted eye, the correction of long sight, the long-sighted eye and the correction of short-sight

(b) the short-sighted eye, the correction of short sight, the long-sighted eye and the correction of long-sight

(c) the long-sighted eye, the correction of short sight, the short-sighted eye and the correction of long sight

(d) none of these



Figs. 8.6 (a) (b) (c) and (d)

43. The three primary colours are

(a) red, green and yellow

(b) red, green and blue

(c) yellow, green and blue

(d) orange, green and violet

44. If an object reflects all the white light falling on it, it appears
    (a) white
    (b) bluish-green
    (c) translucent
    (d) black

45. A yellow flower, when viewed through a piece of blue glass, will appear
    (a) white
    (b) red
    (c) yellow
    (d) black

46. When pure red light passes through a prism,
    (a) it splits into two components
    (b) it splits into three components
    (c) it splits into seven components
    (d) it only gets deviated

47. When an object moves towards a concave lens, the size of the image
    (a) increases
    (b) decreases
    (c) remains unaffected

48. The final image seen in a compound microscope is
    (a) virtual and erect
    (b) real and erect
    (c) virtual and inverted
    (d) real and inverted

49. The magnifying power of an astronomical telescope is 12. If the focal length of the objective is 144 cm, the focal length of the eye-piece is
    (a) 12 cm
    (b) 24 cm
    (c) 20 cm
    (d) 12×144 cm

50. The image formed by a concave lens is always
    (a) inverted and magnified
    (b) inverted and diminished
    (c) erect and magnified
    (d) erect and diminished

51. A myopic eye is corrected by the use of a
    (a) convex lens
    (b) concave lens
    (c) plano-convex lens
    (d) cylindrical lens

52. For a normal eye, the distance between the eye and near point is nearly equal to

(a) 100 cm
(b) 25 cm
(c) 8 cm
(d) 1 cm

53. The least distance of distant vision, with the age of a persons,
(a) varies
(b) does not vary
(c) increases the same for infants and adults
(d) increases for infants and decreases for adults

54. In a myopic eye, rays from infinity are brought to focus at a point.
(a) between the eye lens and the retina
(b) behind the retina
(c) on the retina
(d) none of these

55. Short-sightedness occurs in the eye due to
(a) increase in focal length of the eye lens
(b) reduction in focal length of the eye lens
(c) reduction in distance between the retina and eye lens
(d) none of these

56. Light wavelength visible to the human eye is
(a) 1000 Å
(b) 3000 Å
(c) 6000 Å
(d) 8000 Å

57. The magnification of a compound microscope is
(a) $M = \dfrac{D \times L}{f_o + f_e}$
(b) $M = \dfrac{D \times L}{f_o - f_e}$
(c) $M = \dfrac{D \times L}{f_o \times f_e}$
(d) $M = \dfrac{D + L}{f_o + f_e}$

58. A telescope is an instrument to see
(a) small objects
(b) distant objects
(c) flat objects
(d) circular objects

59. The focal length of the objective of a telescope is
(a) larger than the eyepiece
(b) smaller than the eyepiece
(c) equal to the eyepiece
(d) none of these

60. White light breaks up into seven colours due to
    (a) reflection of light
    (b) refraction of light
    (c) scattering of light
    (d) none of these
61. The light which refracts most is
    (a) red
    (b) violet
    (c) indigo
    (d) yellow
62. Colour blindness is due to
    (a) absence of cone cells
    (b) absence of rod cells
    (c) presence of rod cells
    (d) none of these
63. The rod cells respond to the
    (a) colour of light
    (b) intensity of light
    (c) source of light
    (d) none of these
64. The chicken needs bright light to see because it has
    (a) only cone cells
    (b) only rod cells
    (c) mostly cone and very few rod cells
    (d) mostly rod and very few cone cells
65. The bee can see beyond violet light because it has
    (a) only retinal cone cells
    (b) only rod cells
    (c) mostly retinal cone and very few rod cells
    (d) mostly rod cells and very few cone cells

True or False Statements

1. A convex mirror is used as a shaving mirror
2. The mirror which mostly forms real images has a positive focal length.
3. A concave mirror is called a converging mirror.
4. All distances are measured from the optical centre of a lens.
5. A ray of light goes undeviated on passing through the optical centre.
6. A convex lens has a virtual focus.
7. Concave lens is thicker at the centre and thinner at the corners.
8. A watch maker uses a convex lens.

9. A concave lens never forms a magnified image.
10. The image formed by a concave lens can be real or virtual depending upon the position of the object.
11. Lens formula is given by $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$
12. In an eye, optic nerves convey the image to the brain.
13. The focussing in an eye is done by varying the distance between the lens and retina.
14. The eyelids controls the amount of light entering the eye.
15. In case of hypermetropia, the size of the eye ball becomes smaller than that in a normal eye.
16. Power of a lens is expressed in watts.
17. In order to rectify short-sightedness, we should use a concave lens.
18. The distance of distinct vision for a normal eye is 25 m.
19. In case of a magnifying glass, the shorter the focal length of the convex lens, the greater is its magnifying power.
20. A telescope is used to see a small object magnified.
21. Astigmatism is corrected by making use of a concave lens.
22. If both the surfaces are equally convex, the optical centre lies at the centre of the lens.
23. The focal length of a lens (of power + 20 D) is 0.05 m.
24. A concave lens cannot give a real image of an object.
25. A student wants to make a simple microscope so he should use a convex lens.
26. A compound microscope consists of a convex lens of very short focal length and a concave lens of large focal length.
27. The objective of a compound microscope produces a virtual, erect and enlarged image.
28. When monochromatic light passes through a prism, it splits up into seven colours.
29. A thick lens has more power than a thin lens.
30. The aperture of the objective of an astronomical telescope is smaller than that of the eyepiece

31. Red colour of light has the highest wavelength.
32. The colour of an opaque object depends upon the colour of light falling on the object.
33. Rainbow appears due to splitting of sunlight by the tiny droplets of water in the atmosphere.
34. Colour blind persons do not possess cone cells.
35. The distance of distinct vision is about 25 m.

ANSWERS (OBJECTIVE EVALUATION)

1. (b)	2. (b)	3. (a)	4. (a)	5. (a)	6. (b)	7. (c)	8. (d)	9. (d)
10. (a)	11. (c)	12. (a)	13. (d)	14. (d)	15. (d)	16. (b)	17. (d)	18. (c)
19. (d)	20. (a)	21. (c)	22. (c)	23. (b)	24. (d)	25. (c)	26. (a)	27. (a)
28. (a)	29. (b)	30. (a)	31. (b)	32. (a)	33. (a)	34. (b)	35. (c)	36. (c)
37. (d)	38. (a)	39. (c)	40. (a)	41. (c)	42. (b)	43. (b)	44. (a)	45. (d)
46. (d)	47. (a)	48. (c)	49. (a)	50. (d)	51. (b)	52. (b)	53. (a)	54. (a)
55. (b)	56. (c)	57. (c)	58. (b)	59. (a)	60. (c)	61. (b)	62. (a)	63. (b)
64. (c)	65. (c)							

ANSWERS (TRUE/FALSE)

1. F	2. F	3. T	4. T	5. T	6. F	7. F	8. T	9. T
10. F	11. F	12. T	13. F	14. F	15. T	16. F	17. T	18. F
19. T	20. F	21. F	22. T	23. T	24. T	25. T	26. F	27. F
28. F	29. T	30. F	31. T	32. F	33. T	34. T	35. F	

UNIT NINE
ELECTRICITY AND ITS EFFECTS

REVIEW CONCEPTS

Electric intensity : An electric field may be defined as the space around a charged body where the electric influence is felt. For example, a charged body in the field will experience a force of attraction or repulsion. The intensity or strength of an electric field at any point is numerically equal to the force experienced by a unit charge kept at that point. The SI units for electric intensity is N/C. It is a vector quantity.

Electrostatic potential or electric potential : The electric potential of a body may be explained as the electricl condition of two conductors due to which there is a sharing of charges. In other words, charges will flow from a body at a higher potential to a body at a lower potential. Potential of a body can be increased by adding positive charges (or removing negative charges).

The *standard potential* is that of the earth which is considered to be zero. Thus, potential of a body can be defined as that factor which determines the flow of charges when it is in communication with other bodies. The potential at a point is numerically equal to the work done in bringing a unit positive charge or test charge from infinity to that point. It is a scalar quantity and is expressed in J/C.

Potential difference between two points in an electric field is defined as the work done in bringing a unit positive charge from one point to the other.

Electric current is defined as the rate of flow of charge. For the flow of charge two things are required. Circuit must be closed and there must be a potential difference between the two points. The unit of current is the ampere which is a fundamental unit in the SI system.

Conventional current is defined as the current from high potential (positive) to low potential (negative).

The ***ampere*** is defined as that current, if maintained in two parallel conductors of infinite length and negligible area of cross-

section, placed one metre apart in vacuum, will produce between them a force equal to 2×10^{-7} newton per metre.

A ***Coulomb*** is the practical unit of charge and it is defined as the amount of charge transferred by a current of one ampere in unit time.

Ohm's law : The potential difference between the ends of a conductor varies directly with the current flowing through it, provided the temperature of the conductor remains constant and the physical state of the conductor remains the same.

In a metallic conductor AB whose temperature is constant, which is not subjected to any type of strain. Suppose V is the potential difference between the ends A and B. If I is the current flowing through it (Fig. 9.1) then $V = IR$, where R is a constant known as the resistance of the conductor.

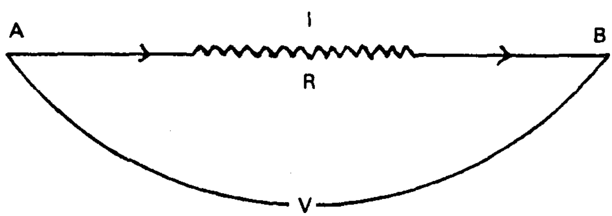


Fig. 9.1 Defining Ohm's Law

Resistance is a measure of the opposition offered by the conductor to the flow of current (or electrons) through it. Resistance is expressed in ohms.

Ohm is the electrical resistance offered between two points of a conductor when a constant potential difference of one volt applied between them produces in the conductor, a current of one ampere; the conductor not being the source of any electromotive force.

Specific resistance (ρ)

The resistance of a conductor, $R = \rho l/A$, where ρ is the specific resistance of the conductor of length l and area of cross-section A. Units of ρ are ohm-metre.

Resistance in series $(R_s) = R_1 + R_2 + R_3 + \ldots$, where R_s is the equivalent resistance when R_1, R_2, R_3, etc. are connected in series with each other.

Current remains same and potential difference is divided in this case.

Resistance in parallel $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$

where R_p is the equivalent resistance when R_1, R_2, R_3, etc. are connected in parallel.

In this case current is divided and potential difference remains the same.

Electromotive force (emf) is defined as the maximum potential difference across the terminals of a cell when no current is flowing in an external circuit. It is a misnomer (wrongly named). Its unit is volt or joule per coulomb.

Heating effect : According to *Joule's law of heating*

(i) The heat developed in a conductor is directly proportional to the square of the current flowing through it, provided the resistance of the conductor and the time for which current is passed remain constant.

(ii) The heat developed in a conductor due to current flowing through it, is directly proportional to the resistance of the conductor, provided the current and the time for which current is passed remain constant.

(iii) The heat developed due to current flowing in a conductor is directly proportional to the time for which the current is passed, provided the resistance of the conductor and the current passing through it remain constant. Heat produced, $H = I^2Rt$.

$$\begin{aligned} \text{Electric Power} &= I^2R \\ &= (IR) \times I \\ &= V \times I \end{aligned}$$

$$1 \text{ watt} = 1 \text{ volt} \times 1 \text{ ampere}$$

The ***Kilowatt-hour*** (kWh) is the unit of energy. It is, the total amount of electrical energy consumed in one hour, when the energy is consumed at the rate of 10^3 J/s.

Unit of electricity

1 unit of electricity = 1 kWh = 3.6×10^6 J.

Insulators are materials which offer infinite resistance to the flow of current. There are no free carriers present in insulators.

Conductors are materials which offer no or very low resistance to the flow of current. There are free carriers present in conductors.

A ***magnet*** has the property of attracting pieces of iron. When it is freely suspended, it always rests in the north-south direction. The region surrounding a magnet, within which the influence of the

magnet can be experienced, is called the *magnetic field* of the magnet. Every magnetic field comprises of an infinite number of lines of force. The *line of force* is defined as a curve, the tangent to which at any point gives the direction of force. The intensity of the magnetic field at any point in the magnetic field is the force experienced by a unit north pole placed at that point.

Magnetic induction (*B*) is the characteristic of a magnetic field and is defined as the force experienced by a conductor of length 1 m, carrying a current of one ampere, when placed in the magnetic field at right angles to the field direction. The SI unit of B is *tesla* or N/A/m. The direction of the magnetic field can be found either by Maxwells's corkscrew rule or right-hand grip rule.

Maxwell's right-hand grip rule. Imagine the wire carrying current, to be gripped with your right hand in such a way that the thumb points along the wire in the direction of the current. Then the direction of the fingers will give the direction of the magnetic lines of force representing the magnetic field.

One ampere is defined as that amount of current which, if flowing in two thin straight parallel wires of infinite length placed 1 m apart in air (or vacuum), will produce on each other a force of 2×10^{-7} N/m.

When a conductor (length l) carrying a current I is placed in a magnetic field B, it will experience a force given by

$$F = BIl$$

The direction of the force is perpendicular to the magnetic field.

Electromagnetism : Magnetism due to flow of current is called electromagnetism.

Field due to a solenoid : The magnetic field due to a long circular coil carrying current is very strong. The two ends of the solenoid behave as two poles.

An ***electromagnet*** is a magnet whose magnetism arises due to the flow of current. The strength of an electromagnet depends upon

(i) amount of current flowing
(ii) the number of turns of the coil
(iii) nature of the core

Fleming's left hand rule is used to find out the direction of motion of a conductor when placed in a magnetic field.

Forefinger represents the direction of the field
Middle finger represents the direction of current then
Thumb represents the direction of motion of the conductor.

Fleming's right hand rule is used to find out the direction of current

Forefinger represents the direction of magnetic field

Thumb represents the direction of motion of the conductor

then the Middle finger gives the direction of current.

An ***electric motor*** works on the principle that whenever a current carrying conductor is placed in a magnetic field, it experience a force given by Fleming's left hand rule.

Armature is a soft iron piece on which wire is wound which rotates in the magnetic field.

Electromagnetic induction is the phenomenon of producing induced current in a moving conductor in a magnetic field. It was discovered by Faraday. The direction of the induced current is given by Fleming's right hand rule.

A ***dynamo*** is an electrical device which works on the principle of electromagnetic induction. The armature rotates in the magnetic field and current is produced. A motor and dynamo are just opposite to each other.

AC Dynamo is the one which produces alternating current i.e., in which the direction of the induced current changes alternatively after equal intervals of time. In this case we use slip rings due to which the direction of the current changes.

DC Dynamo is the one which produces direct current i.e., the direction of the current remains the same. In case of DC dynamo split rings called commutator are used, which give current only in one direction.

Transmission of electricity is done mainly as AC. The voltage is stepped up by using a transformer, in order to reduce the power loss.

Household circuits : All appliances are connected in parallel so that each may get equal voltage and if one is switched off or on, others are not affected. There are three wires in domestic circuits, red, black and green. Red is live, black is neutral and green is earth. All switches are connected to the live wire. The live wire is the one which carries current.

A ***fuse*** is a device used for the safety of appliances and electric circuits against excessive heating during a short circuit or overloading. It is a low melting point wire connected to the live wire. Generally it is a wire of pure tin or an alloy of tin and lead (63% tin and 37% lead).

Earth connections are done to prevent a person from getting an electric shock.

Formulae

1. Potential difference

$$V = \frac{W}{Q} \text{ or } W = V \times Q$$

Also $W = (V_B - V_A) \times Q$

where
V = potential difference
W = work done
Q = charge
V_B and V_A = potential at two different points

2. Current

$$I = \frac{q}{t} \quad \text{or} \quad I = \frac{nq}{t}$$

where
I = current
Q = charge
n = number of carriers and
t = time

3. Ohm's law

$$V = I \times R$$

or

$$I = \frac{V}{R} \quad \text{or} \quad R = \frac{V}{I}$$

where
I = current
V = potential difference and
R = resistance

4. Power

$$P = \frac{W}{t}$$

Also

$$P = V \times I \Rightarrow I = \frac{P}{V}$$

or

$$P = I^2R$$

where,
P = power
W = work done (energy consumed)
V = potential difference
I = current
t = time and
R = resistance

5. Energy(H)

$$W = I^2Rt \quad \text{also,} \quad H = V \times I \times t$$

(symbols have the usual meaning)

6. Cost

$$\text{Cost} = W \times \text{rate}$$

where $W = P \times t$

$$\text{Cost} = P \times t \times \text{rate}$$

7. Resistance in series

$R = R_1 + R_2 + R_3 + \ldots$ where R = resultant (equivalent resistance)

$R_1, R_2, R_3, \ldots$ are individual resistances

8. Resistance in parallel

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$

NUMERICAL PROBLEMS (SOLVED)

EXAMPLE 1 The charge of one electron is 1.602×10^{-19} C.How many electron charges make one coulomb ?

Solution: Given,

Charge of 1 electron (q) = 1.602×10^{-19} C

Total charge (Q) = 1 C

To calculate : Number of electrons (n) = ?

Formula to be used : $Q = n \times q$

or $n = \frac{Q}{q}$

Substituting the given values we get,

$$n = \frac{1}{1.602 \times 10^{-19}}$$

$$= \frac{10^{19}}{1.602} = 6.24 \times 10^{18} \text{ electrons}$$

EXAMPLE 2 What will be the current drawn by an electric bulb of 40 W, when it is connected to a source of 220 V ?

Solution: Given,

Power (P) = 40 W

Potential difference (V) = 220 V

To calculate : Current (I) = ?

Formula to be used : $P = V \times I$

$$= I = \frac{P}{V}$$

Substituting the given values, we get,

$$I = \frac{40}{220} = 0.18 \text{ A}$$

EXAMPLE 3 A simple electric circuit has a 24 V battery and a resistor of 60 ohms. What will be the current in the circuit? The resistance of the connecting wires are negligible.

Solution: Given,

Potential difference (V) = 24 V

Resistance (R) = 60 ohms

To calculate : Current (I) = ?

Formula to be used : $I = \frac{V}{R}$

Putting the value of V and R in the above equation and simplifying

$$I = \frac{24}{60}$$

$$I = 0.4 \text{ A}$$

EXAMPLE 4 A current of 4 A flows through a 12 V car head light bulb for 10 minutes. How much energy transfer occurs during this time ?

Solution: Given,

Current (I) = 4 A

Voltage (V) = 12 V

Time (t) = 10 min = 600 s

To calculate : Energy transfer (H) = ?

Formula to be used : $H = V \times I \times t$

Substituting the given values, we get,

$$H = 12 \times 4 \times 600$$

$$= 28800 \text{ Joule}$$

$$= 28.8 \times 10^3 \text{ Joule}$$

EXAMPLE 5 Six equal resistances of 1Ω each are connected to form

the sides of a hexagon ABCDEF. Calculate the resistance offered by the combination if the current enters at A and leaves at D.

Solution: Given,

Six resistors each of value $= 1\Omega$

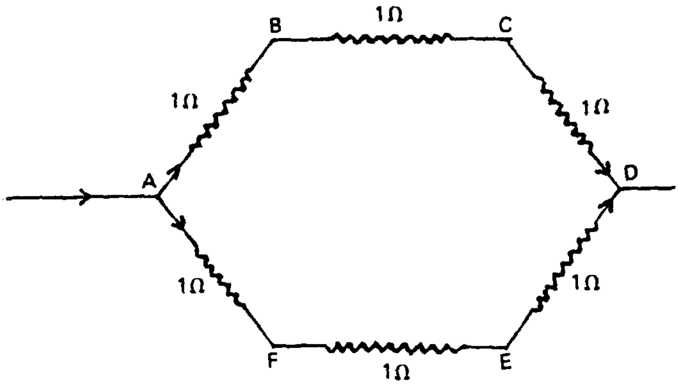


Fig. 9.2

To calculate : Resistance (R) of the combination $= ?$

Formula to be used : (i) $R_{ABCD} = R_1 + R_2 + R_3$ (in series)

$$\text{(ii)}\ \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

Resistance of the branch ABCD,

$$R_{ABCD} = 1 + 1 + 1$$

$$R_{ABCD} = 3\Omega$$

Similarly, resistance of the branch AFED,

$$R_{AFED} = 1 + 1 + 1$$

$$R_{AFED} = 3\Omega$$

Since R_{ABCD} and R_{AFED} are in parallel, the required resistance is given by

$$\frac{1}{R} = \frac{1}{R_{ABCD}} + \frac{1}{R_{AFED}}$$

It follows from Fig. 9.6 that the total resistance is equivalent to (4 + 12) and (2 + 6), in parallel. Let the required resistance be R

$$\frac{1}{R} = \frac{1}{16} + \frac{1}{8}$$

$$= \frac{1+2}{16} = \frac{3}{16}$$

or $$R = \frac{16}{3} = 5.33\ \Omega$$

EXAMPLE 8 One billion electrons pass from a point A towards another point B in 10^{-4} s. What is the current in amperes ? What is its direction ?

Solution: Charge of one electron (q) = 1.6×10^{-19} C

Number of electrons (n) = 10^9 (one billion)

Time (t) = 10^{-4} s

To calculate : (i) Current (I) = ?

(ii) Direction of I = ?

Formula to be used : $I = \dfrac{n \times q}{t}$

Substituting the given values,

$$I = \frac{10^9 \times 1.6 \times 10^{-19}}{10^{-4}}$$

$$= 1.6 \times 10^{-10} \times 10^4$$

$$= 1.6 \times 10^{-6}\ \text{A}$$

Direction of current flows is from B to A. Since electrons are negatively charged.

EXAMPLE 9 An electric heater is used on a 220 V supply and takes a current of 5 ampere.

(i) What is its power ?

(ii) What is the cost of using the heater for 30 days if 1 kWh costs 50 paise.

Solution: Given,

Potential difference (V) = 220 V

Current (I) = 5 A

Time (t) = 30 days = 30×24 = 720 hrs

Rate = 50 paise per unit

To calculate : (i) Power (P) = ?

(ii) Cost = ?

Formula to be used : (i) $P = V \times I$

(ii) Cost = $P \times t \times$ rate

Substituting the value of V and I in the first formula, we get

$$P = 220 \times 5$$
$$= 1100 \text{ watts}$$
$$= 1.1 \text{ kW}$$

(ii) Cost = $1.1 \times 720 \times 0.50$

= Rs. 3.96

EXAMPLE 10 For a heater rated at 4 kW and 220 V, calculate

(i) the current

(ii) the resistance of the heater

(iii) the energy consumed in 2 hrs. and

(iv) the cost of 1 kWh is priced at 50 paise

Solution: Given,

Power (P) = 4 kW = 4000 Watt

Potential difference (V) = 220 V

Time (t) = 2 hr = 7200 s

To calculate : (i) current (I) = ?

(ii) resistance (R) = ?

(iii) Energy consumed (E) = ?

(iv) cost = ?

Formula to be used : (i) $I = \frac{P}{V}$

(ii) $R = \frac{V}{I}$

(iii) $E = P \times t$

(iv) cost = $t \times$ rate

Substituting the given values

(i) Current (I) $= \dfrac{4000}{220} = 18.1$ A

(ii) Resistance (R) $= \dfrac{V}{I} = \dfrac{220}{18.1} = 12.1\,\Omega$

(iii) Energy (E) $= P \times t$

$= 4 \times 2 = 8$ kilowatt/hr

(iv) Cost $= E \times$ rate

$= 8 \times \dfrac{50}{100} =$ Rs. 4.00

EXAMPLE 11 The electric potential at a point in an electric field is 200 V. How much work will have to be done to make an electron from that point to a point just outside the field ? Given charge on an electron $= 1.6 \times 10^{-19}$ C.

Solution: Given,

Potential difference (V) $= 50000$ V

Charge on an electron (q) $= 1.6 \times 10^{-19}$ C

To calculate : Energy (W) = ?

Formula to be used : $W = V \times q$

$W = 50000 \times (1.6 \times 10^{-19})$

$= 80000 \times 10^{-19}$

$= 8.0 \times 10^{-15}$ J

EXAMPLE 13 How much work is done in moving a charge of 2 C from a point at 118 V to a point at 128 V?

Solution: Given,

Charge (q) = 2 C

Potential at one point (V_A) = 118 V

Potential at the other point (V_B) = 128 V

To calculate : Work done (W) = ?

Formula to be used : $W = (V_B - V_A) \times q$

$W = (128 - 118) \times 2$

$= 20$ J

EXAMPLE 14 Two bulbs have the following ratings

(a) 40 W, 200 V

(b) 20 W, 110 V

What is the ratio of their resistance ?

Solution: Given,

Power $(P) = 40$ W

Voltage $(V_1) = 200$ V

Power $(P_2) = 20$ W

Voltage $(V_2) = 110$ V

To calculate : Ratio of the resistances (R_1, R_2)

where R_1 and R_2 are the resistances of two bulbs respectively.

Formula to be used : $P = VI$

$$= \frac{V^2}{R}$$

=> $$R = \frac{V^2}{P}$$

using this formula for both the bulbs, we get

$$R_1 = \frac{V_1^2}{P_1} \quad \text{and} \quad R_2 = \frac{V_2^2}{P_2}$$

$$\frac{R_1}{R_2} = \frac{V_1^2}{V_2^2} \times \frac{P_2}{P_1}$$

$$= \frac{(200)^2}{(110)^2} \times \frac{20}{40}$$

$$= \frac{2}{1}$$

$$R_1 : R_2 :: 2 : 1$$

EXAMPLE 15 Two lamps, one rated at 100 W, 220 V and the other 60 W, 220 V are connected in parallel to a 220 V supply. What current is drawn from the supply line ?

Solution: Given,

Power $(P_1) = 100$ W

Power $(P_2) = 60$ W

Voltage $(V_1) = 220$ V

$$\text{Voltage } (V_2) = 220 \text{ V}$$

Bulbs are connected in parallel.

To calculate : Current (I) = ?

Formula to be used : $\text{Current } (I) = \dfrac{V}{R}$

Since we don't know the value of R so first of all we will calculate the value of R_1 and R_2 and then find out the equivalent re- sistance by using the formula for resistances in parallel.

$$\text{Resistance of the first lamp } (R_1) = \frac{V_1^2}{P_1}$$

$$= \frac{220 \times 220}{100}$$

$$= 484\ \Omega$$

$$\text{Resistance of the second lamp } (R_2) = \frac{V_2^2}{P_2}$$

$$= \frac{220 \times 220}{60}$$

$$R_2 = \frac{4840}{6}$$

$$= 806.6\ \Omega$$

$$\text{Resultant resistance } (R) = \frac{R_1 \times R_2}{R_1 + R_2}$$

$$= \frac{484 \times 4840}{(484 + 4840/6)\ 6}$$

$$= \frac{484 \times 4840}{1290.67 \times 6}$$

$$R = 302.6\ \Omega$$

$$\text{Current } I = \frac{V}{R}$$

$$= \frac{220 \times 1290.67 \times 6}{484 \times 4840}$$

$$I = 0.727 \text{ A}$$

EXAMPLE 16 You are provided with two bulbs operating on 220 V, one of 60 W and the other of 100 W. If the two are connected in series and then the combination is connected to 440 V, which of them will fuse and why ?

Solution: Given,

Power (P_1) = 60 W

Power (P_2) = 100 W

Voltage (V_1) = 220 V

Combination connected to a voltage (V_2) = 440 V

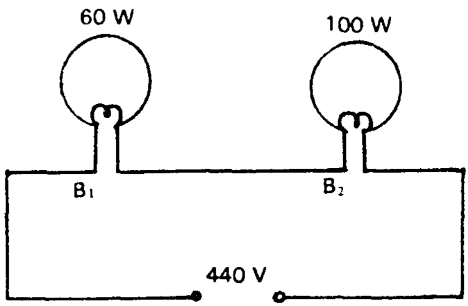


Fig. 9.7

To calculate : Which bulb will fuse first.

Now, to find out this we will have to find out the amount of maximum current that can flow through each of the bulb.

Formula to be used : $I = \frac{P}{V}$

Maximum current (I_1) through B_1

$$= \frac{P_1}{V_1} = \frac{60}{220}$$

$$I_1 = 0.27 \text{ A}$$

Similarly, the maximum current (I_2) through B_2

$$= \frac{100}{220} = 0.45 \text{ A}$$

Now B_1 and B_2 are connected in series to a voltage V_2 = 440 V

So we will first find out the resistance in series.

To find out resistance.

$$R_1 = \frac{V_1}{I_1} = \frac{220}{0.27} = 814 \ \Omega$$

and $$R_2 = \frac{V_1}{I_2} = \frac{220}{0.45} = 488\ \Omega$$

Total resistance $R = R_1 + R_2$

$$= 814 + 488 = 1302\ \Omega$$

Current (I) in the circuit $= \frac{V_2}{R} = \frac{440}{1302}$

$$I = 0.33\ \text{A}$$

But $I > I_1$ therefore B_1 will fuse first since only 0.27 A can pass through B_1.

EXAMPLE 17 I can spend Rs. 9.00 per month (30 days) on electric light. If power is 30 paise per kWh and I use 5 identical bulbs for 5 hours a day, what should be the power of each bulb ?

Solution: Given,

Total cost = Rs. 9.00

Cost of each unit (1 kWh) = 30 paise = 0.30 Rs.

Number of bulbs = 5

Time for which bulbs run daily = 5 hr.

Number of days = 30

To calculate : Power (P) = ?

Let the power of each bulb = P

Total power = $5 \times P$ (since all bulbs are identical)

$$\text{Number of units which I can use} = \frac{\text{Total cost}}{\text{rate}}$$

$$= \frac{9.00}{0.30} = 30$$

i.e., I can consume 30 units of energy

Number of hours = 30×5 = 150 hrs.

$$\text{Power } (P) = \frac{\text{No. of kilowatt hrs.}}{\text{No. of hours}}$$

$$= \frac{30 \times 1000}{150}\ \text{Watts}$$

$$P = 200\ \text{Watts}$$

Therefore power of each bulb $= \frac{200}{5}$

$$P = 40 \text{ W}$$

i.e., I can use 5 bulbs of 40 Watts each.

EXAMPLE 18 An electric iron used for ironing clothes is marked 400 W and 220 V. What is its resistance when iron is hot? How long could it be used for three rupees if electrical energy costs 15 paise a unit?

Solution: Given,

Power (P) = 400 W

Voltage (V) = 220 V

Cost = Rs. 3.0

Rate = 15 paise per unit = Rs. 0.15 per unit

To calculate : (i) Resistance (R) = ?

(ii) Time (t) = ?

Formula to be used : (i) $R = \frac{V}{I}$

(ii) $t = \frac{W}{P}$

(i) $R = \frac{V}{I}$ But $I = \frac{P}{V}$

$$= I = \frac{400}{220}$$

$$R = \frac{220 \times 220}{400} = 121\,\Omega$$

(ii) $t = \frac{W}{P}$

But we do not know the value of W, so we will first find out the value of W.

$$\text{Total energy} = \frac{\text{Cost}}{\text{rate}} = \frac{3.00}{0.15}$$

$$W = 20 \text{ kWh} = 20 \times 10^3 \text{ Watt hr}$$

$$t = \frac{W}{P} = \frac{20 \times 1000}{400} = 50 \text{ hrs.}$$

EXAMPLE 19 A circuit consists of 1 wire in series with a parallel arrangement of 6 and 3 wires. Calculate the total resistance of the circuit.

Solution: Given,

Resistance $(R_1) = 1\,\Omega$

Resistance $(R_2) = 6\,\Omega$

Resistance $(R_3) = 3\,\Omega$

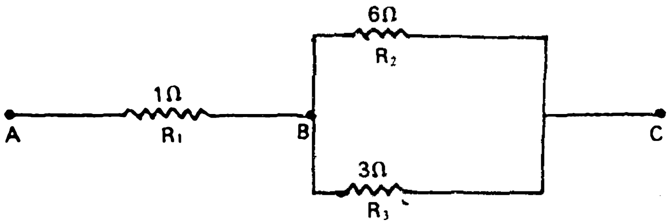


Fig. 9.8

Also R_2 and R_3 are connected in parallel and the resultant of R_2 and R_3 (R_{23}) is connected in series with R_1.

To calculate : Resultant Resistance $(R) = ?$

Formula to be used : (i) $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$

(ii) $R = R_1 + R_2$

Since R_2 and R_3 are connected in parallel.

Using formula no. (i), we get

$$\frac{1}{R_{23}} = \frac{1}{R_2} + \frac{1}{R_3}$$

$$= \frac{1}{6} + \frac{1}{3} = \frac{1+2}{6}$$

$$\frac{1}{R_{23}} = \frac{3}{6} = R_{23} = 2\,\Omega$$

Now this R_{23} and R_1 are in series.

Using (ii), we get,

$$R = R_1 + R_{23}$$

$$= 1 + 2 = 3\,\Omega$$

EXAMPLE 20 Compute the number of electrons passing per minute through an electric bulb of 60 W, 220 V.

Solution: Given,

Power $(P) = 60$ W

Voltage $(V) = 220$ V

Time $= 1$ minute $= 60$ s

Charge on an electron $(q) = 1.6 \times 10^{-19}$ C

To calculate : No. of electrons $(n) = ?$

Formula to be used : $$n = \frac{I \times t}{q} \quad \text{(i)}$$

Since in this equation/case we do not know that value of I, therefore our prime aim is to find the value of I using the formula

$$I = \frac{P}{V}$$

$$I = \frac{60}{220} = \frac{3}{11} \text{ A}$$

Substituting this value of I and the value of t and q in equation (i) we get,

$$n = \frac{3}{11} \times \frac{60}{1.6 \times 10^{-19}}$$

$$= \frac{180 \times 10^{19}}{11 \times 1.6} = 1.02 \times 10^{20}$$

$$n = 1.02 \times 10^{20} \text{ electrons.}$$

EXAMPLE 21 A current of 10 A flows through a straight wire. Calculate the magnetic induction at a point 2 cm from the wire. The permeability of the free space is 4×10^{-7} N/A^2.

Solution: Given,

Current $(I) = 10$ A

Distance $(r) = 2$ cm $= 0.02$ m

Permeability of free space $(\mu_o) = 4\pi \times 10^{-7}$ N/A^2

To calculate : Magnetic induction $(B) = ?$

Formula to be used : $$B = \frac{\mu_o I}{2\pi r}$$

Substituting the given values

$$B = \frac{4\pi \times 10^{-7} \times 10}{2 \times \pi \times 0.02}$$

$$B = 10^{-4}\ \text{T}$$

EXAMPLE 22 A wire 10 cm long and carrying a current of 1.5 A is held in a uniform magnetic field in which $B = 10^{-3}$ T. Calculate the force on the wire if it is held perpendicular to the lines of the magnetic field.

Solution: Given,

Length of the wire (l) = 10 cm = 0.10 m

Current (I) = 1.5 A

Magnetic induction (B) = 10^{-3} T

To calculate : Force (F) = ?

Formula to be used : $F = BI$

Substituting the given values, we get,

$$F = 10^{-3} \times 1.5 \times 0.1$$

$$F = 15 \times 10^{-5}\ \text{N}$$

EXAMPLE 23 A current of 10 A flows in a circular coil of 1000 turns and radius 0.1 m. Find the magnitude of the magnetic field at the centre of the circular coil.

Solution: Given,

Current (I) = 10 A

Number of turns (n) = 1000

Radius (r) = 0.1 m

Permeability (μ_o) = $4\pi \times 10^{-7}$ N/A^2

To calculate : Magnetic field at the centre of the coil (B) = ?

Formula to be used : $B = \dfrac{\mu_o I \times m}{2r}$

Substituting the given values,

$$B = \frac{4\pi \times 10^{-7} \times 1000}{2 \times 0.1}$$

$$B = 6.28 \times 10^{-2}\ \text{Wb/m}^2$$

EXAMPLE 24 At what distance from a straight conductor (carrying a current of 2.8 A) will the magnetic induction be 2.8×10^{-5} T ?

$$\mu_o = 4\pi \times 10^{-7} \text{ N/A}^2$$

Solution: Given,

Current $I = 2.8$ A

Magnetic induction $(B) = 2.8 \times 10^{-5}$ T

Permeability $(\mu_o) = 4\pi \times 10^{-7}$ N/A^2

To calculate : Distance $(r) = ?$

Formula to be used : $B = \dfrac{\mu_o I}{2\pi r}$

=> $$r = \frac{\mu_o I}{2\pi B}$$

$$= \frac{4\pi \times 10^{-7} \times 2.8}{2\pi \times 2.8 \times 10}$$

$$r = 0.05 \text{ m}$$

EXAMPLE 25 Find the strength of the current which will produce a magnetic field of 10^{-4} T at the centre of a coil of mean radius 0.10 m. The coil comprises 20 turns.

Solution: Given,

Magnetic Induction $(B) = 10^{-4}$ T

Radius $(r) = 0.10$ m

Number of turns $(n) = 20$

Permeability $(\mu_o) = 4\pi \times 10^{-7}$ N/A^2

To calculate : Current $(I) = ?$

Formula to be used : $B = \dfrac{\mu_o I}{2\pi r}$

=> $$I = \frac{B \times 2\pi r}{\mu_o}$$

Substituting the given values,

$$I = \frac{10^{-4} \times 2 \times \pi \times 0.10}{4\pi \times 10^{-7}}$$

$$I = 0.796 \text{ A}$$

EXAMPLE 26 A 0.4 m wire, stretched horizontally, carries an electric current of 15 A from east to west, in a magnetic field whose magnetic field intensity is 0.1 N/Am, directed vertically downwards. What is

(a) the magnitude of the magnetic deflecting force on the wire, and
(b) its direction?

Solution: Given,

Length of the wire (l) = 0.4 m

Current (I) = 15 A

Magnetic induction (B) = 0.1 N/Am

To calculate : (i) Force (F) = ?

(ii) Direction = ?

Formula to be used : $F = BI$

Substituting the given values,

$$F = 0.1 \times 15 \times 0.4$$

$$F = 0.6 \text{ N}$$

(ii) By Fleming's left hand rule, forefinger (magnetic field) points vertically downwards, the middle finger (current) points west and the thumb (force) points towards the south.

EXAMPLE 27 A horizontal wire 0.10 m long carries a current of 5 A. Find the magnitude and direction of the field that can support the wire, assuming its mass to be 3.0×10^{-3} kg/m.

Solution: Given,

Length of the wire (l) = 0.10 m

Current (I) = 5 A

Mass per unit length (m) = 3.0×10^{-3} kg/m

Acceleration due to gravity (g) = 9.8 m/s^2

To calculate : (i) Magnetic field (B) = ?

(ii) Direction = ?

Formula to be used : $BIl = F$

or $BIl = mg$

=> $B = \dfrac{mg}{Il}$

The magnetic field should be such that it generates a force in the upward direction so that the gravitational pull on the wire is balanced.

Substituting the given values,

$$B = \frac{3 \times 10^{-3} \times 0.1 \times 9.8}{5 \times 0.1}$$

$$B = 5.88 \times \times 10^{-3} \text{ T}$$

EXAMPLE 28 Two long parallel wires carry currents 2.0 A and 4.0 A respectively in opposite directions. The separation between the wires is 0.25 m. Calculate the force per unit length between them. Take $\mu_o = 4\pi \times 10^{-7}$ N/A^2.

Solution: Given,

Current (I_1) = 2.0 A

Current (I_2) = 4.0 A

Distance (d) = 0.25 m

Permeability (μ_o) = $4\pi \times 10^{-7}$ N/A^2

To calculate : Force (F) = ?

Formula to be used : $F = \dfrac{\mu_o I_1 I_2}{2\pi d}$

Substituting the given values,

$$F = \frac{4\pi \times 10^{-7} \times 2.0 \times 4.0}{2 \times \pi \times 0.25}$$

$$F = 6.4 \times 10^{-6} \text{ N/m}$$

This force is repulsive in nature since current is flowing in the opposite direction.

NUMERICAL PROBLEMS (UNSOLVED)

1. Calculate the force on an electron in a field of 1500 N/C. Take the charge of an electron to be 1.6×10^{-19} C.
   (Ans. 2.4×10^{-16} N)

2. Three resistances, each equal to 5 Ω, are connected in series with a cell of 1.2 V. Find the magnitude of current in the circuit.
   (Ans. 0.08 A)

3. An electric bulb connected to a 220 V supply line draws a current of 0.15 A. Calculate the amount of coulombs per second flowing through the bulb. (Ans. 0.15 C/s)

4. The resistances of 5 Ω, 10 Ω and 15 Ω are connected in series and a potential difference of 1.5 V is applied across the extreme ends. Calculate the current passing through the circuit.
   (Ans. 0.05 A)

5. An equilateral triangle is formed with each side having a resistance of 2 Ω. What is the effective resistance across any side ? (Ans. 4/3Ω)

6. A battery of 6 V is connected in series with three resistors of 12 Ω, 6 Ω and 4 Ω as shown in Fig. 9.9 is the current through each of the resistors the same ? Calculate the potential difference across each resistor.

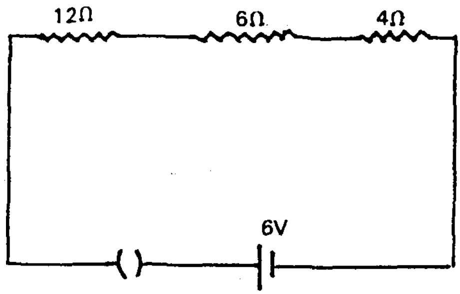


Fig. 9.9

7. In the circuit shown in Fig. 9.10, calculate the
(a) current flowing through the arms AB, AC and CDE
(b) potential difference across AB, CD and DE.

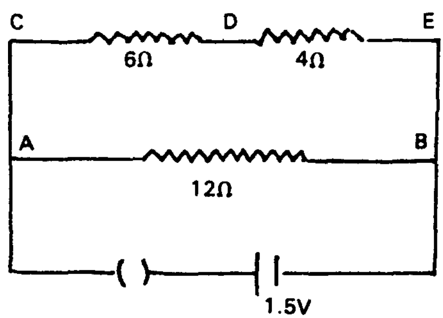


Fig. 9.10

8. Fifty lamps each of resistance 100 Ω are connected in parallel across a 220 V mains. Find (a) the power consumed in watts, and (b) the cost of operating the lamps for 20 hours at 10 paise per kWh.
(Ans. (a) 24,200 W, and (b) Rs. 48.40)

9. Three equal resistors connected in series across a source of emf together dissipate 10 W of power. What should be the power

dissipated if the resistors are connected in parallel across the same emf? (Ans. 90 W)

10.(a) In the network shown in Fig. 9.11, what is the total resistance between A and B? (Ans. 4/3 Ω)

(b) The resistance of two conductors joined in series is 8 Ω and in parallel is 1.5 Ω. Show that the resistance are 6 Ω and 2 Ω respectively.

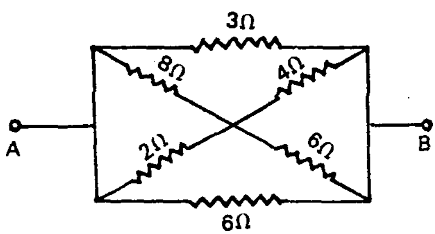


Fig. 9.11

11. In the network shown below (Fig. 9.12) calculate the effective resistance between A and B. (Ans. 7 Ω)

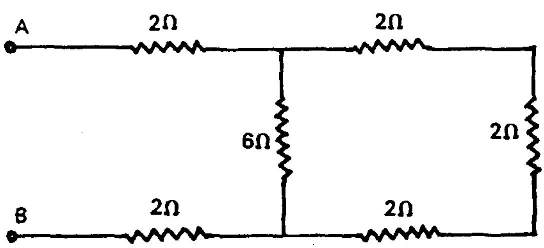


Fig. 9.12

12. A cloud is at a potential of 2×10^4 V relative to the ground. When lightning strikes the ground, a charge of 86 C is transferred to the ground. Calculate the work done. (Ans. 1.72×10^6 J)

13. Prove, by taking an example, that the resistance of the combination is always less than the least single resistance in the arrangement, in the case of resistances connected in parallel.

14. In the following circuit (Fig. 9.13) prove that

$$I_1R_1 = I_2R_2$$

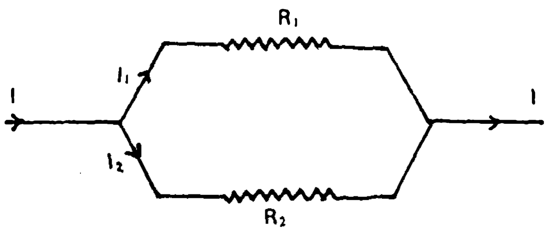


Fig. 9.13

15. If electrons are caused to fall through a potential difference of 10^5 V, determine their final speed if they were initially at rest. (Ans. 2.3×10^8 m/ s)

16. A charged body has lost 10^3 electrons. Find the magnitude of charge on the body. (Ans. 1.6×10^{-6} C)

17. Two electrons are 1 A apart, show that the force between them is 2.304×10^{-5} N.

18. How many electrons must be removed from a pith ball to give it a charge of 6.4×10^{-12} C? (Ans. 4×10^7)

19. Find the electrical force between the electrons and proton of the normal hydrogen atom and compare it with the gravitational force between them. Given : mass of proton = 1.7×10^{-27} kg, average separation between the electron and proton = 5.3×10^{-11} m, and G = 6.67×10^{-11} N m²/kg².
(Ans. $F_e = 8.2 \times 10^{-8}$ N, $F_g = 3.67 \times 10^{-47}$ N, $F_e/F_g = 2.234 \times 10^{39}$)

20. How much work is required to be done to move a charge of 10^{-6} C from a point at a potential of 1000 V to another point at 1025 V ? (Ans. 2.5×10^{-5} J)

21. An electric heater has a resistance of 12 Ω and is operated from a 220 V power line. If no heat escapes from it, how much time

is required to raise the temperature of 40 kg of water from 15°C to 80° C ? (Ans. 2703 s)

22. Two bulbs have the following ratings:

    (a) 60 W, 200 V

    (b) 30 W, 100 V

    What is the ratio of their resistances ? (Ans. 2 : 1)

23. Two bulbs rated at 25 W, 110 V and 100 W, 110 V are connected in series to a 220 V electric supply. Find out which of the two bulbs will fuse ? What would happen if the two bulbs were connected in parallel to the same supply ?

    (Ans. The first bulb would fuse, both the bulbs would fuse)

24. An electric heater consumes 5 A of current when run on 220 V mains. Find the cost of running it for 7 hrs. when the electric energy is supplied at 30 paise per unit ? (Ans. Rs. 2.31)

25. A 1000 W electric heater is used on a 220 V supply. What is the current in the heater ? Also, calculate the resistance of the element. (Ans. 4.55 A, 48.4 Ω)

26. What maximum voltage can be placed across a 10,000 Ω resistor if it is rated for 0.25 W ? (Ans. 50 V)

27. Calculate the force experienced by a conductor of length 0.2 m carrying a current of 0.8 A, when placed in a uniform magnetic field of intensity 1.2 Wb/m^2. (Ans. 0.192 N)

28. Calculate the force experienced by a conductor of length 0.3 m carrying a current of 1 A, when placed in a uniform magnetic field of intensity 1.2 N/A^2. (Ans. 0.36 N)

29. A horizontal conducting wire of length 0.05 m carries a current of 1 A. Calculate the magnetic field required to support the weight of the wire. Mass of the wire is 1.5×10^{-4} kg.

    (Ans. 2.94×10^{-2} T)

30. Two long parallel wires carry currents of 4 A and 8 A, respectively, in opposite directions. The separation between them is 0.25 m. Calculate the force per unit length between them. Take $\mu_o = 4\pi \times 10^{-7}$ N/ A^2. (Ans. 25.6×10^{-6} N/m)

31. A current of 4 m is passed through a straight wire of length 3 cm

in a uniform perpendicular magnetic field of 12 T. What is the magnetic force experienced the wire ? (Ans. 1.44×10^{-3} N)

32. A current of 1 A flows in a circular coil of 100 turns and radius 0.1 m. Calculate the magnetic field at the centre of the coil. (Ans. 6.3×10^{-4} T)

33. A long straight wire carries a current of 10 A. Calculate the magnetic field at a distance of 0.2 m from the wire due to the current. (Ans. 10^{-5} T)

34. A long wire carries a current of 1.0 A. What is the magnetic field at a point 0.15 m from the wire ? (Ans. 1.33×10^{-6} N/Am)

35. A wire carrying a current of 5.0 A, perpendicular to a magnetic field of 1.0 N/Am, experiences a force of 1 N. Calculate the length of the wire. (Ans. 0.20 m)

OBJECTIVE EVALUATION

1. When a body is negatively charged by friction, it means
   (a) the body has acquired excess of electrons
   (b) the body has acquired excess of protons
   (c) the body has lost some electrons
   (d) the body has lost some neutrons

2. An electric charge on a body produces
   (a) a magnetic field only
   (b) an electric field only
   (c) both electric and magnetic field
   (d) neither electric nor magnetic field

3. There is no flow of current between two charged bodies when connected because
   (a) they have the same quantity of charge
   (b) they have the same potential
   (c) they have the same capacity
   (d) they have the same ratio of potential charge

4. If a charged body attracts another body, the charge on the other body
   (a) may be negative
   (b) may be positive
   (c) may be zero
   (d) may be negative or positive

5. The unit of emf is
   (a) dyne (c) volt
   (b) newton (d) ampere
6. Electromotive force represents
   (a) force (c) energy
   (b) energy per unit charge (d) work
7. When a conductor gets charged due to the mere presence of another charged body, the phenomenon is called
   (a) conduction (c) friction
   (b) induction (d) convention
8. Materials which allow larger currents to flow through them are called
   (a) insulators (c) semi-conductors
   (b) conductors (d) alloys
9. If I is the current throught a wire and e is the charge of electron, then the number of electrons in t seconds will be given by
   (a) $I_e\ /t$ (c) e/It
   (b) Ite (d) It/e
10. Conventionally the direction of the current is taken as
    (a) the direction of flow to negative charge
    (b) the direction of flow of atoms
    (c) the direction of flow of molecules
    (d) the direction of flow of positive charge
11. Ohm's law states that
    (a) $V \propto I$ for constant R
    (b) $V \propto I$ for variable R
    (c) $V \propto \frac{1}{I}$ for constant R
    (d) $V \propto \frac{1}{I}$ for variable R
12. Kilowatt-hours $= \dfrac{\text{volt} \times \text{ampere} \times \text{———}}{1000}$
    (a) time in seconds (c) time in days
    (b) time in minutes (d) time in hours
13. The commonly used safety fuse wire is made of
    (a) tin (c) lead
    (b) nickel (d) an alloy of tin and lead

14. The speed of an electric fan is adjusted with the help of an external variable resistance called a
    (a) rheostat
    (b) jockey
    (c) two-way key
    (d) none of these
15. Choose the correct relationship :
    (a) 1 kWh $= 36 \times 10^5$ J
    (b) 1 kWh $= 3.6 \times 10^3$ J
    (c) 1 kWh $= 3.6 \times 10^8$ J
    (d) none of these
16. Mica is used in electric irons because it is
    (a) a good conductor of electricity
    (b) a bad conductor of electricity
    (c) a bad conductor of heat
    (d) a bad conductor of both heat and electricity
17. Watt-day is the unit of
    (a) mechanical power
    (b) thermal power
    (c) electrical power
    (d) none of these
18. Kilowatt-hour is the unit of
    (a) power
    (b) impulse
    (c) energy
    (d) none of these
19. The kilowatt-hour is commonly known as
    (a) watt-hour
    (b) unit
    (c) watt-day
    (d) none of these
20. In a safety fuse, the temperature to which the wire gets heated is inversely proportional to the
    (a) radius of the wire
    (b) cube of the radius of the wire
    (c) square of the radius of the wire
    (d) fourth power of the radius of the wire
21. In a safety fuse, the temperature to which the wire gets heated is directly proportional to the
    (a) the square of the current
    (b) the fourth power of the current
    (c) the cube of the current

22. In a safety fuse, the temperature to which the wire gets heated does not depend upon
    (a) the radius of the wire
    (b) the type of alloy used
    (c) the length of the fuse wire
    (d) the magnitude of the current

23. If V be the change in potential between two neighbouring points r apart, then the electric field E is given by

    (a) $E = \Delta V \times \Delta r$ (c) $E = \dfrac{\Delta r}{\Delta V}$

    (b) $E = \dfrac{\Delta V}{\Delta r}$ (d) $E = \dfrac{(\Delta V)^2}{\Delta r}$

24. A man has five resistors each of value $1/5\,\Omega$. What is the maximum resistance he can obtain by connecting them ?
    (a) $1\,\Omega$ (c) $5\,\Omega$
    (b) $\frac{1}{2}\,\Omega$ (d) $2/5\,\Omega$

25. What is the minimum resistance that one can obtain by combining all the five resistances given in Q. 24 ?
    (a) $1/10\,\Omega$ (c) $1/5\,\Omega$
    (b) $1/50\,\Omega$ (d) $1/25\,\Omega$

26. How will the reading in the ammeter A of Fig. 9.14 be affected if another identical bulb Q is connected in parallel to P ? The voltage in the mains is maintained at a constant value.

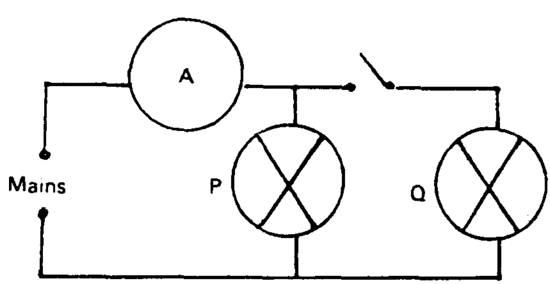


Fig. 9.14

(a) the reading will be reduced to one half
(b) the reading will not be affected
(c) the reading will be double the previous one
(d) the reading will be increased four-fold

27. In the circuit shown below (Fig. 9.15) the ammeter A reads 5 A and the voltmeter V reads 20 V. The correct value of resistance R is
(a) exactly 4 Ω
(b) slightly less than 4 Ω
(c) slightly greater than 4 Ω
(d) zero

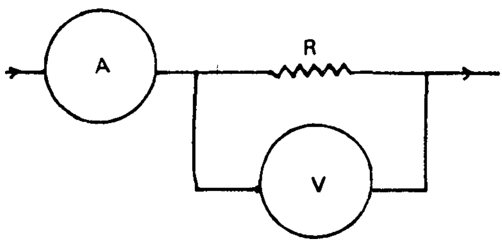


Fig. 9.15

28. The unit of specific resistance is
(a) Ω
(b) Ω m
(c) m Ω
(d) Ω^{-1}

29. If the length of a wire is doubled and its cross-section is also doubled then
(a) the resistance will increase four times
(b) the resistance will decrease four times
(c) the resistance will increase two times
(d) the resistance will remain unchanged

30. In the circuit shown (Fig. 9.16) the reading of the voltmeter V will be
(a) 4 V
(b) 6 V
(c) 2 V
(d) 3 V

31. Five identical resistance coils are connected in the network, as shown in Fig. 9.17 and the resistance measured between A and B is found to be 1 Ω. Then the individual coils must have resistances of

(a) $1/4\ \Omega$ (c) $4/7\ \Omega$
(b) $7/4\ \Omega$ (d) $1\ \Omega$

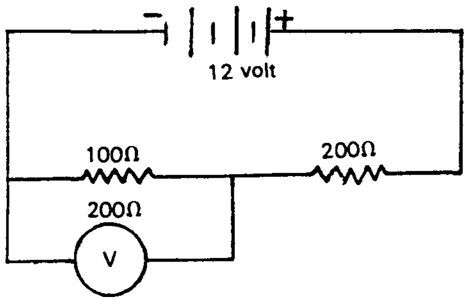


Fig. 9.16

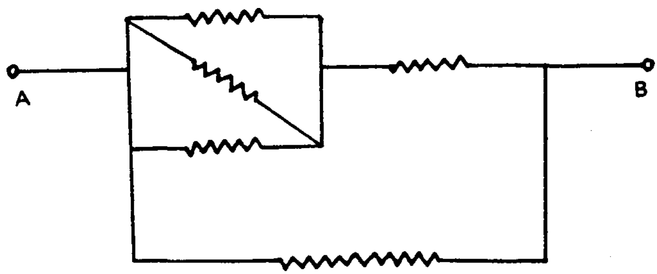


Fig. 9.17

32. It is a common notion that the earth's magnetism is due to the
    (a) presence of a huge permanent magnet in the interior of the earth
    (b) presence of electric currents circulating in the interior of the earth
    (c) influence of the sun's magnetic field
    (d) influence of a nuclear explosion
33. The force between two parallel wires carrying current has been used to define
    (a) ampere (c) volt
    (b) coulomb (d) watt

34. A magnetic field cannot exert any force on a
    (a) moving magnet
    (c) stationary magnet
    (b) moving charge
    (d) stationary charge

35. The force of repulsion between two parallel wires is f when each one of them carries a certain current I. If the current in each is doubled, the force between them would be
    (a) F/f
    (c) $2f$
    (b) $4f$
    (d) f

36. An electric iron draws a current of 4 A when connected to a 220 V mains. Its resistance must be
    (a) 1000 Ω
    (c) 55 Ω
    (b) 44 Ω
    (d) none of these

37. Electro volt is the unit of
    (a) potential difference
    (c) energy
    (b) current
    (d) charge

38. A suitable unit for expressing electric field strength is
    (a) V/C
    (c) Am
    (b) C/m^2
    (d) N/C

39. The effective resistance of a circuit containing resistances in parallel is
    (a) equal to the sum of the individual resistances
    (b) smaller than any of the individual resistances
    (c) greater than any of the individual resistances
    (d) sometimes greater and sometimes smaller than the individual resistances

40. Electric intensity is
    (a) a scalar quantity
    (b) a vector quantity
    (c) neither scalar nor vector
    (d) sometimes scalar and sometimes vector

41. Electric potential is
    (a) a scalar quantity
    (b) a vector quantity
    (c) neither scalar nor vector
    (d) sometimes scalar and sometimes vector

42. One ohm is equal to
    (a) 10^6 mega ohm (MΩ)
    (b) 10^9 MΩ
    (c) 10^{-6} MΩ
    (d) none of these
43. In general, when the temperature of a conductor increases, its resistance
    (a) increases
    (b) decreases
    (c) remains the same
44. The resistance of carbon __________ with rise in temperature.
    (a) increases
    (b) decreases
    (c) remains the same
    (d) first increases then decreases
45. The resistance of a semiconductor material (germanium or silicon) __________ with rise in temperature.
    (a) increases
    (b) decreases
    (c) remains the same
    (d) first increases then decreases
46. The reciprocal of resistance is conductance. The unit of resistance is ohm. Therefore, the unit of conductance is
    (a) ohm
    (b) henry
    (c) mho
    (d) moles/litre
47. In Coulomb's law, the constant of proportionality K has the units
    (a) N
    (b) Nm^2
    (c) NC^2/m^2
    (d) Nm^2/C^2
48. The magnitude of K in the above question in Nm^2/C^2 is
    (a) 9×10^5
    (b) 9×10^{11}
    (c) 9×10^3
    (d) none of these
49. 1 volt equals
    (a) 1 J
    (b) 1 C/J
    (c) 1 J/C
    (d) none of these
50. A graph is plotted between the potential difference (applied

across the ends of a conductor) and the current (flowing through the conductor). The graph is a straight line

(a) intersecting both the axes

(b) having an intercept on the X-axis

(c) having an intercept on the Y-axis

(d) none of these

51. In order to measure current in a resistance present in a circuit, the ammeter is connected.

(a) in series

(b) in parallel

(c) in series or parallel

52. Good conductors have many loosely bound

(a) atoms

(b) protons

(c) molecules

(d) electrons

53. In our houses all electrical devices operate on 220 V. It implies that

(a) they are connected in parallel

(b) they are connected in series

(c) they all have currents of equal values

(d) they all have the same resistance

54. What is the total resistance across A and B in the circuit shown in Fig. 9.18 ?

(a) 1 Ω

(b) 2 Ω

(c) 1.5 Ω

(d) none of these

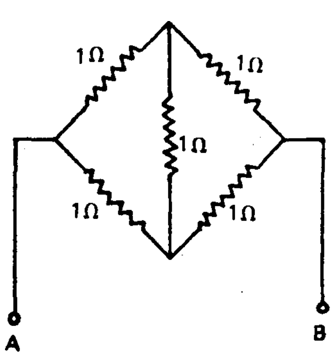


Fig. 9.18

55. What will be the total resistance across A and B in the circuit shown in Fig. 9.19 ?

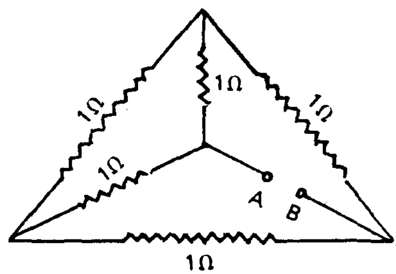


Fig. 9.19

(a) 1 Ω (c) 1.5 Ω

(b) 2 Ω (d) none of these

56. Given three equal resistors, how many different combinations can be made ?

(a) 2 (c) 4

(b) 3 (d) 6

57. In which of the circuits shown in Fig. 9.20 will the galvanometer (whose resistance G = 100 Ω) show no deflection ?

58. How many electrons constitute a current of one micro ampere ?

(a) 6×10^6 (c) 6×10^{12}

(b) 6×10^9 (d) 6×10^{15}

59. A person connects four 1/4 Ω cells in series but one cell has its terminals reversed. The external resistance is 1 Ω. If each cell has an emf of 1.5 V, the current flowing is

(a) $\frac{4}{3}$ A (c) $\frac{3}{4}$ A

(b) 1.5 A (d) zero

60. In the network shown in Fig. 9.21 the equivalent resistance between P and Q will be

(a) 7 (c) 2

(b) 5/3 (d) 1

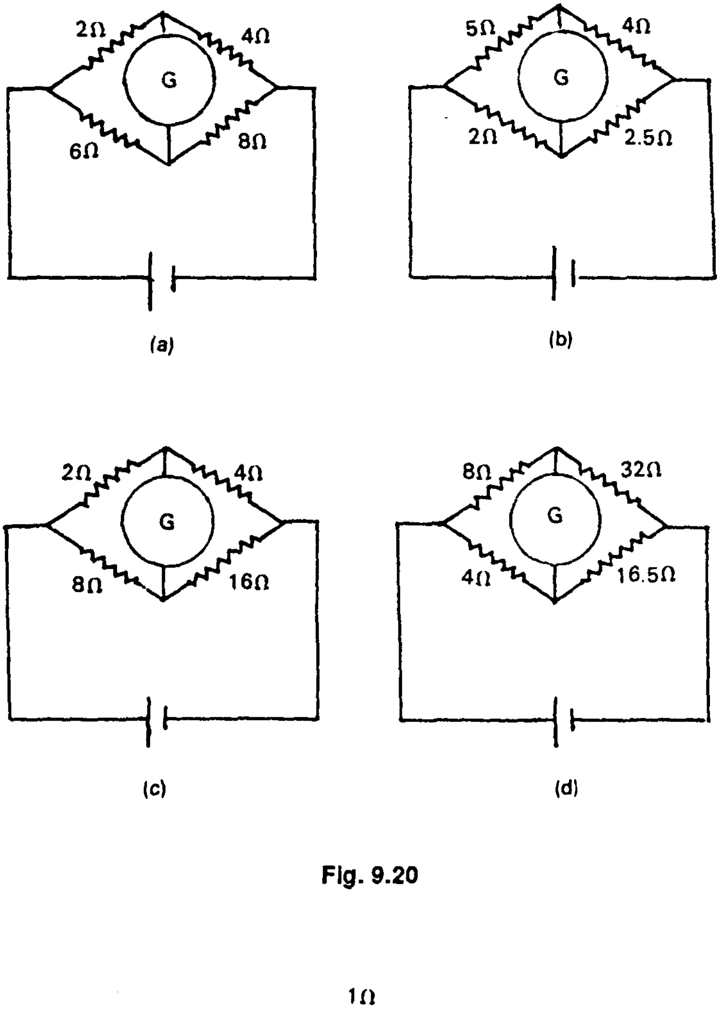


Fig. 9.20

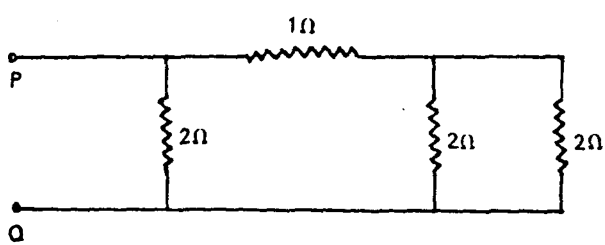


Fig. 9.21

61. Which switch in the circuit in Fig. 9.22 when closed will produce short circuiting ?

(a) A
(b) B
(c) C
(d) none of the above

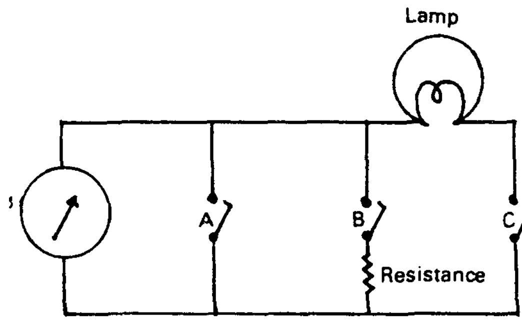


Fig. 9.22

62. Seven identical lamps of resistance 2200 Ω each are connected to a 220 V line as shown in Fig. 9.23. Then the reading in the ammeter will be

(a) 1/10A
(b) 3/10A
(c) 4/10A
(d) none of these

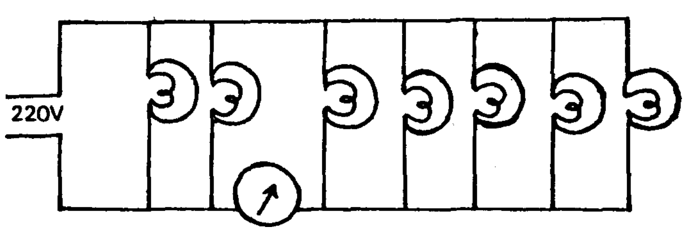


Fig. 9.23

63. The resistance of a conductor is reduced to half its initial value. In doing so the heating effects in the conductor will become

(a) half
(b) double
(c) one-fourth
(d) four times

64. The coil of a heater is cut into two equal halves and only one of them is used in the heater. The ratio of the heat produced by this half of the coil to that produced by the original coil is

(a) 2 : 1 (c) 1 : 2
(b) 4 : 1 (d) 1 : 4

65. Three equal resistors connected in series across a source of emf together dissipates 10 W power. If the same resistors are connected in parallel across the same emf the power dissipated will be
(a) 30 W (c) 10 W
(b) 90 W (d) 10/3 W

66. In the circuit shown below (Fig. 9.24) the heat produced in the 5 Ω resistor due to the current flowing through it is 10 cal/s. The heat generated in the 4 Ω resistor is
(a) 2 cal/s (c) 4 cal/s
(b) 3 cal/s (d) none of these

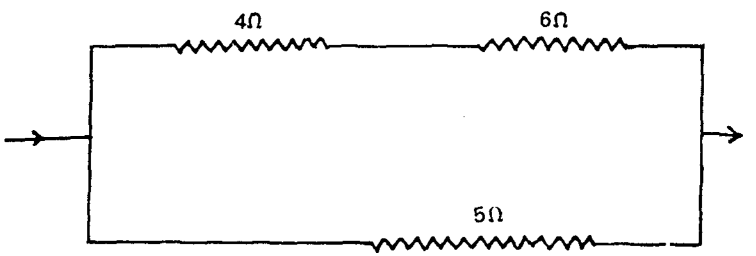


Fig.9.24

67. In Fig. 9.25 what is the total resistance across A and B ?
(a) 0.5 (c) 1.5
(b) 2.5 (d) 1.0

68. Three identical bulbs are connected to a battery as shown in Fig. 9.26. When the circuit is closed by means of the switch S, it is found that
(a) R will be bright but Q and P dim
(b) P, Q are R, all will be equally bright
(c) Q and R will immediately burn out
(d) P will be bright, but Q and R dim

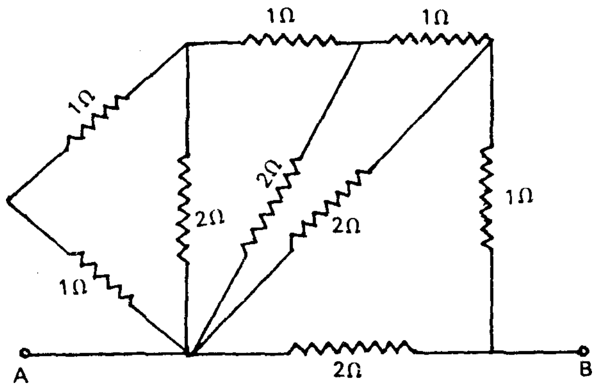


Fig. 9.25

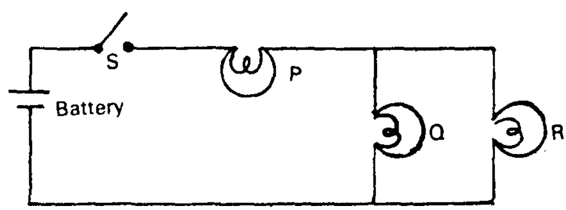


Fig. 9. 26

69. The fact that current is associated with a magnetic field was discovered by

    (a) Oersted (c) Faraday

    (b) Maxwell (d) Ohm

70. Ampere rule is used to find the

    (a) direction of current

    (b) direction of magnetic field

    (c) direction of motion of the conductor

    (d) magnitude of current

71. A magnetic field cannot exert any force on a
    (a) stationary charge
    (b) moving charge
    (c) stationary magnet
    (d) moving magnet

72. A compass needle just above a wire in which electrons are moving to the east, will point
    (a) east
    (b) west
    (c) north
    (d) south

73. Choose the correct statement.
    (a) lines of force are not imaginary lines
    (b) lines of force cannot be mapped on paper
    (c) lines of force do not intersect each other
    (d) lines of force always intersect each other

74. A motor converts
    (a) mechanical energy into electrical energy
    (b) mechanical energy into sound energy
    (c) electrical energy into mechanical energy
    (d) electrical energy into sound energy

75. A dynamo converts
    (a) mechanical energy into sound energy
    (b) mechanical energy into electrical energy
    (c) electrical energy into mechanical energy
    (d) electrical energy into sound energy

76. By inserting a soft iron piece into a solenoid the strength of the magnetic field
    (a) increases
    (b) decreases
    (c) first increases then decreases
    (d) remains unchanged

77. By increasing the number of turns in the coil, the strength of the magnetic field
    (a) decreases
    (b) increases
    (c) first decreases then increases
    (d) remains unchanged

78. If the current in the core decreases, the strength of the magnetic field
    (a) decreases
    (b) increases
    (c) sometimes decreases and sometimes increases
    (d) remains unchanged

79. The unit of magnetic flux is
    (a) Weber (c) Tesla
    (b) Gauss (d) Weber/m^2

80. Fleming's right hand rule gives
    (a) the magnitude of the induced emf
    (b) the magnitude of the magnetic field
    (c) the direction of the induced emf
    (d) both magnitude and direction of the induced emf

81. The unit of induced emf is
    (a) ampere (c) joule
    (b) volt (d) electron volt

82. The phenomenon of electromagnetic induction was discovered by
    (a) Lenz (c) Fleming
    (b) Maxwell (d) Faraday

83. For making an electromagnet the best material for the case is
    (a) stainless steel (c) soft iron
    (b) silver (d) nickel

84. The intensity of a magnetic field is defined as the force experienced by a
    (a) standard compass (c) unit negative charge
    (b) unit positive charge (d) unit north pole

85. A wire carrying a current of 5 A is placed perpendicular to a magnetic induction of 2 T. The force on each centimetre of the wire is
    (a) 0.1 N (c) 10 N
    (b) 100 N (d) 1 N

86. There will be no force between two currents if they are
    (a) parallel to each other

(b) antiparallel to each other
(c) perpendicular to each other

87. A long current carrying wire PQ is free to move when placed in a magnetic field B at right angles to the wire, as shown in Fig. 9.27 (the figure being drawn in the horizontal plane). Then
(a) it will move along the magnetic field to the right
(b) it will move upwards, towards the observer
(c) it will move downwards, away from the observer
(d) it will not move at all

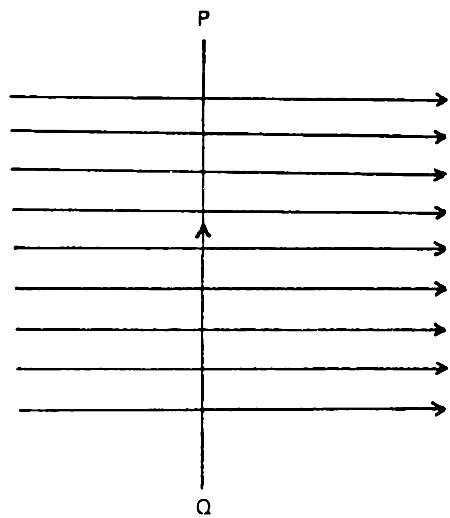


Fig. 9.27

88. A long straight wire carries a heavy current. An electron is travelling parallel to the wire in the opposite direction to the current. The electron experiences a force f when its distance from the wire is 1 m. If the electron was travelling in a direction perpendicular to the wire, then the force on it when it is 1 m from the wire, its

(a) f
(b) $2f$
(c) $f/2$
(d) zero

89. A certain length of wire carries a steady current. It is bent to form a circular plane coil of one turn. The same length is now bent more sharply to give a double loop of smaller radius, as shown in Fig. 9.28. The magnetic field at the centre caused by the same current is

(a) a quarter of its first value

(b) unaltered

(c) four times its first value

(d) one half its first value

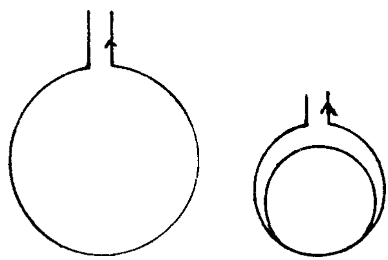


Fig. 9.28

90. Two long parallel conductors are placed at right angles to the metre scale, at the 2 cm and 6 cm marks, as shown in Fig. 9.29.

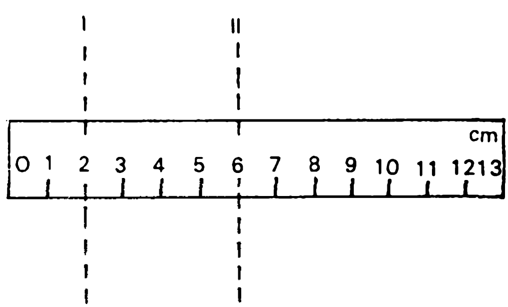


Fig. 9.29

They carry currents 1 A and 3 A respectively. They will produce zero magnetic field at the

(a) zero mark (c) 3 cm mark

(b) 10 cm mark (d) 6 cm mark

91. The relation between weber and tesla is

(a) $1\ \text{Wb} = 1\ \text{T}$ (c) $1\ \text{Wb} = 1\ \text{T} \times 1\ \text{m}$

(b) $1\ \text{Wb} = 1\ \text{T} \times 1\ \text{m}^2$ (d) $1\ \text{Wb}^2 = 1\ \text{T} \times 1\ \text{m}^2$

92. When the normal to a coil points in the direction of B, the flux is

(a) a scalar quantity

(b) a vector quantity

(c) neither scalar nor vector

94. Lenz's law is a consequence of the law of conservation of

(a) energy (c) angular momentum

(b) momentum (d) charge and mass

95. In a DC generator, the induced emf in the armature is

(a) DC (c) fluctuating DC

(b) AC (d) both AC and DC

96. The induced emf due to the motion of a conductor in a uniform magnetic field is known as motional emf. If l is the length of the conductor, V is the speed of conductor and B is the magnetic induction, then the induced emf is given by

(a) $\frac{Bl}{V}$ (c) $-BlV$

(b) $\frac{BV}{l}$ (d) none of these

97. The emf produced in a wire by its motion across a magnetic field does not depend upon

(a) the length of the wire

(b) the composition of the wire

(c) the speed of the wire

(d) the orientation of the wire

98. A metallic rod falls under gravity with its ends pointing east and west. Then

(a) an emf is induced in it as it cuts the magnetic lines of force

(b) no emf is induced at all
(c) two emf's of equal but opposite signs are induced, giving no net emf.
(d) its acceleration is equal to the product of g and the radius of the ring

100. A copper ring is moved towards the north pole of a bar magnet.
(a) The ring will not be affected
(b) The ring will tend to get warm
(c) An alternating current will flow in the ring
(d) The ring will be positively charged

101. A circular coil and a bar magnet recede from each other with the same velocity. Then
(a) there will be no induced emf in the coil
(b) there will be an induced emf in the coil
(c) an emf will be induced in the magnet

102. The split rings in motion are called
(a) armature (c) commutator
(b) rotor (d) core

103. In a hydel station, the motion produced in turbines is due to the
(a) burning of coal (c) flow of water
(b) burning of diesel (d) production of steam

104. The frequency of AC mains is
(a) 100 Hertz (c) 1/100 Hertz
(b) 50 Hertz (d) 1/50 Hertz

105. At grid sub-stations the voltage is stepped up to reduce loss of
(a) current (c) power
(b) electrical energy (d) resistance

106. A switch is always connected to the
(a) earth wire (c) live wire
(b) neutral wire (d) none of these

107. A fuse wire is always connected to the
(a) earth wire (c) live wire
(b) neutral wire (d) none of these

108. Electricians use rubber gloves while working because
(a) rubber is an insulator
(b) rubber is a good conductor

(c) it is easy to work while wearing gloves
(d) none of these

109. In the resting state, the neutron is
(a) rich in K^+ ions inside
(b) rich in Na^+ ions inside
(c) rich in K^+ ions outside
(d) rich in Na^+ ions outside

110. The shape of an electrolyte cell is
(a) flat
(b) circular
(c) cylindrical
(d) like an electric wire

True or False Statements

1. Ohm's law does not apply to radio valves and transistors.
2. An ammeter is always connected in series in the circuit.
3. A voltmeter can only be connected in series in the circuit.
4. A voltmeter has low resistance.
5. Current is a vector physical quantity.
6. The safety fuse is always connected in series with the electrical installation.
7. The wire used in a safety fuse has high melting point.
8. The electromagnet used in an electric bell is a temporary magnet.
9. The charge of an electron is larger than a Coulomb.
10. A kilowatt hour is larger than a joule.
11. An electron volt is larger than a joule.
12. $1eV = 1.602 \times 10^{-19}$ C
13. $1kWh = 3.6 \times 10^6$ joules
14. The positive and negative charges produced by rubbing two materials are equal in magnitude.
15. The materials in which charges move easily are called insulators.
16. The materials in which charges are bound are called conductors.

17. The human body is a poor conductor of electricity.
18. The unit of resistance is ohm, which is equal to volt/ ampere.
19. In case of resistances in parallel $I = I_1 + I_2 + I_3 + \ldots$.
20. The rate at which energy is dissipated is called power.
21. The potential of earth is taken as infinite.
22. The earth wire is connected to the heating element of an immersion heater.
23. The magnetic lines of force produced by a straight current carrying conductor are straight in nature.
24. Slip rings are used in an AC generator.
25. The graph between V and I for constant R is a straight line.
26. Right hand thumb rule is used to find the direction of the current in electromagnetic induction.
27. Overloading is due to the direct contact between live and the neutral wire.
28. We do not receive an electric shock due to the earth connection.
29. For a transmission line of given resistance, the current should be as small as possible so that power loss is minimum.
30. As the resistance of an electric appliance increases, the power consumed by it also increases.
31. Negative terminal of a battery is at a higher potential than the positive terminal.
32. The strength of an electromagnet increases or decreases the amount of current flowing through it.
33. The thinner the fuse wire, the greater its capacity.
34. The SI unit of electrical potential is the Coulomb.
35. A commutator is used in a DC dynamo.

ANSWERS (OBJECTIVE EVALUATION)

1. (a)	2. (b)	3. (b)	4. (d)	5. (c)	6. (b)	7. (b)	8. (b)	9. (d)
10. (d)	11. (a)	12. (d)	13. (d)	14. (a)	15. (a)	16. (b)	17. (d)	18. (c)
19. (b)	20. (b)	21. (a)	22. (c)	23. (b)	24. (a)	25. (d)	26. (c)	27. (c)
28. (b)	29. (d)	30. (d)	31. (b)	32. (b)	33. (a)	34. (d)	35. (b)	36. (c)
37. (c)	38. (d)	39. (b)	40. (b)	41. (a)	42. (c)	43. (a)	44. (b)	45. (b)
46. (c)	47. (d)	48. (d)	49. (c)	50. (d)	51. (a)	52. (d)	53. (a)	54. (a)

55. (a)	56. (c)	57. (c)	58. (c)	59. (b)	60. (d)	61. (a)	62. (d)
63. (a)	64. (a)	65. (b)	66. (a)	67. (d)	68. (d)	69. (a)	70. (b)
71. (a)	72. (d)	73. (c)	74. (c)	75. (b)	76. (a)	77. (b)	78. (a)
79. (a)	80. (c)	81. (b)	82. (d)	83. (c)	84. (d)	85. (a)	86. (c)
87. (b)	88. (a)	89. (c)	90. (c)	91. (c)	92. (a)	93. (b)	94. (a)
95. (b)	96. (c)	97. (b)	98. (a)	99. (c)	100. (b)	101. (a)	102. (c)
103. (c)	104. (b)	105. (c)	106. (c)	107. (c)	108. (a)	109. (a)	110. (a)

ANSWERS (TRUE/FALSE)

1. T	2. T	3. F	4. F	5. F	6. T	7. F	8. T	9. F
10. T	11. F	12. F	13. T	14. T	15. F	16. F	17. F	18. T
19. T	20. T	21. F	22. F	23. F	24. T	25. T	26. T	27. F
28. T	29. T	30. T	31. F	32. F	33. F	34. F	35. T	

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